ME 53 NUMBER 5 . . . ONE YEAR FOUR DOLLARS

GENERAL ELECTRIC REVIEW

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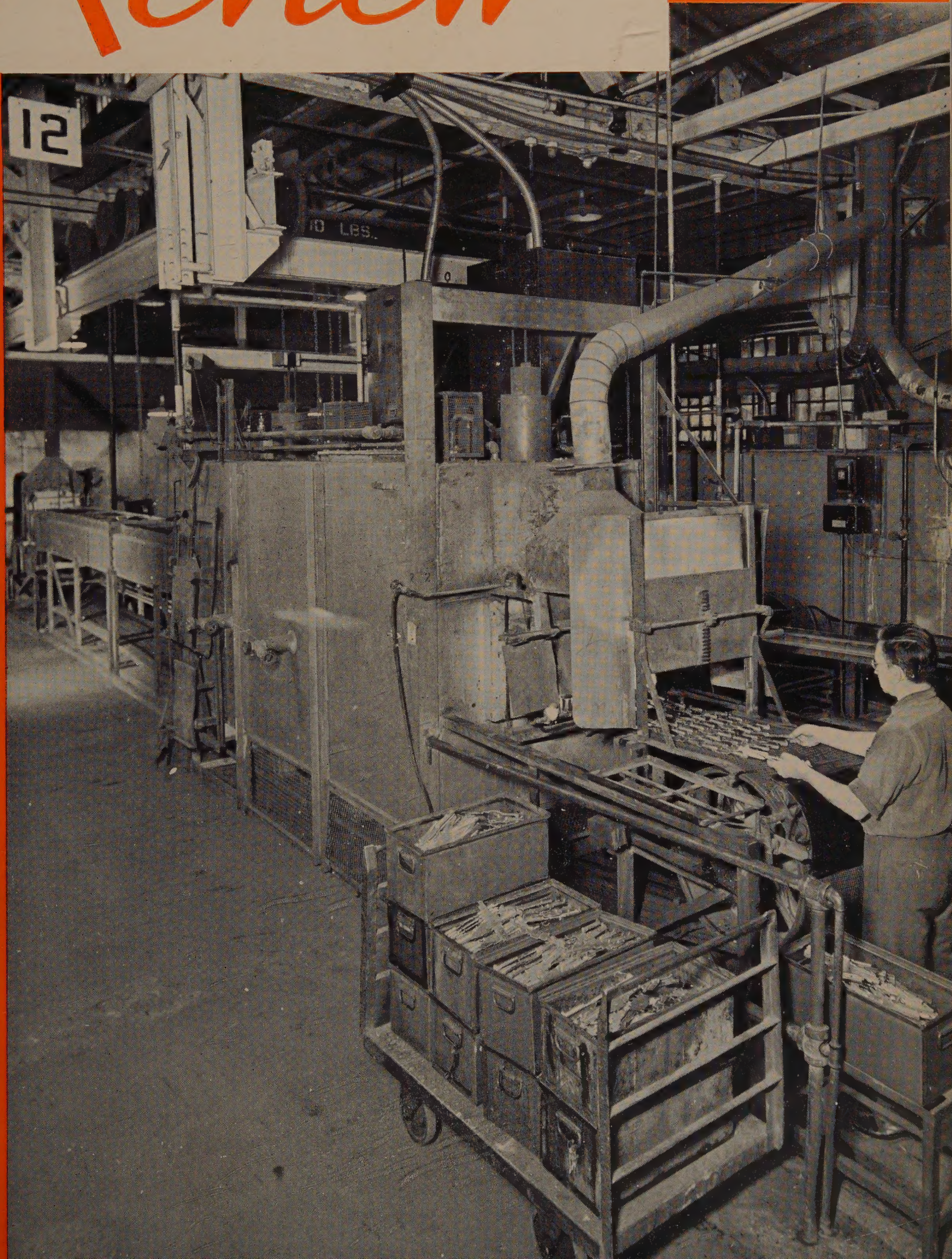
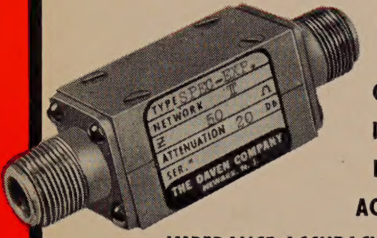
MAY
1950



NEW!... R. F. AND VIDEO COMPONENTS FOR PRECISE CONTROL

In keeping with the Daven policy of continually developing new components to meet the electronic industry's new needs, we are once again first to offer video and radio frequency fixed and variable attenuators. These units embody the characteristics which have come to be synonymous with the name DAVEN . . . excellence of workmanship, top-notch design, finest materials and accurate, efficient performance.

R. F. FIXED ATTENUATORS



TYPE RF-155

CIRCUIT: π network.

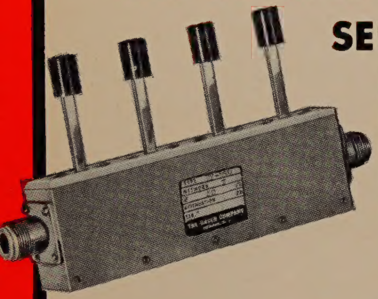
IMPEDANCE: 50 ohms.

LOSS: 5 to 20 DB.

ACCURACY: ± 2% at D.C.

IMPEDANCE ACCURACY: Same as series RF-540

R. F. VARIABLE ATTENUATORS



SERIES RF-540

CIRCUIT: π network.

IMPEDANCE: 50 ohms.

NO. OF STEPS: 4 (push-buttons.)

RESISTOR ACCURACY: ± 2% at D.C.

IMPEDANCE ACCURACY: Terminal impedance of loss network essentially flat from 0-225 MC.

LOSS:

Type RF-540—1, 2, 3, 4 DB (10 DB total.)

Type RF-541—10, 20, 20, 20 DB (70 DB total.)

Type RF-542—2, 4, 6, 8 DB (20 DB total.)

Type RF-543—20, 20, 20, 20 DB (80 DB total.)

SUGGESTED APPLICATIONS

- In signal generators.
- In field strength measuring equipment.
- Nucleonic and atomic research.
- Television receiver testing.
- Wide-band amplifiers.
- Pulse amplifiers.
- Any application where attenuation of UHF is required.

Patent applied for.

VIDEO FIXED ATTENUATORS

TYPE V-154

CIRCUIT: "T" network or equivalent.

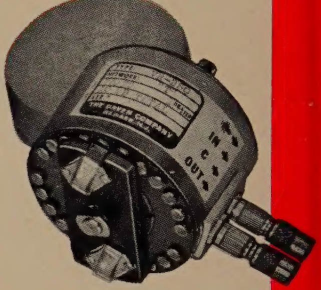
IMPEDANCE: 75 ohms.

LOSS: 1 to 20 DB.

ACCURACY: ± 1% at D.C.

FREQUENCY CHARACTERISTICS: Essentially flat to 10 MC.

VIDEO VARIABLE ATTENUATORS



SERIES V-250

CIRCUIT: "T" network.

IMPEDANCE: 75 ohms.

RESISTOR ACCURACY: ± 1% at D.C.

FREQUENCY CHARACTERISTICS: Essentially flat to 10 MC.

TYPE	NO. OF STEPS	DB PER STEP	TOTAL DB
V-250	10	1	10
V-251	10	2	20
V-252	20	1	20
V-253	20	2	40

These units will be supplied with co-axial connectors or regular terminal boards with lugs.

NOTE: *A video push-button control, similar to the R.F. push-button unit shown, is available.* ***Additional information will be furnished on request.***

SUGGESTED APPLICATIONS

- In television video circuits where a wide frequency range without change of impedance is of special importance.
- Wide-band amplifiers.
- Pulse amplifiers.

THE DAVEN CO.
191 CENTRAL AVENUE
NEWARK 4, NEW JERSEY

GENERAL ELECTRIC Review

MAY 1950
Vol. 53, No. 5

J. S. SMITH
Manager

E. C. SANDERS
Executive Editor

J. E. GLICK
Associate Editor

THE COVER

Steel stampings for industrial control devices are being processed in this mesh-belt conveyor-type electric furnace. The annealed stampings emerge from the cooling chamber clean and bright, ready without pickling to be reformed, plated, and assembled. This bright-annealing process is typical of a variety of quality-improving cost-saving jobs accomplished by protective atmospheres that have been described in the serial which is concluded in this issue. (*See p. 26*).

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New Dust-Tight Plug-in Enclosure for CLARE TYPE "J" TWIN CONTACT RELAY To Meet Severe Operating Conditions

Steel cover, securely held by a slotted-head screw, is easily removed for inspection.

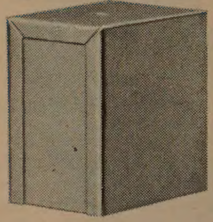
● This new CLARE dust-tight plug-in enclosure for the small Type "J" Relay offers designers a number of unusual features for installation on industrial equipment.

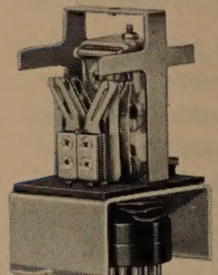
Entrance of dust is prevented by the steel cover and by use of a Neoprene gasket which is closely fitted at the factory to the relay terminals. The dust-tight cover is easily removed for inspection. Use of standard radio plug simplifies installation and cuts wiring costs. Base is secured to chassis to prevent plug from being jarred or accidentally pulled from its socket.

Exclusive design of the CLARE Type "J" Relay allows the twin contacts to operate independently of each other. One contact is sure to close, reducing contact failure to the practical limit. This relay combines all the best features of the conventional telephone-type relay with small size and light weight. It provides unusually high current-carrying capacity, large contact spring capacity, extreme sensitivity and high operating speed.

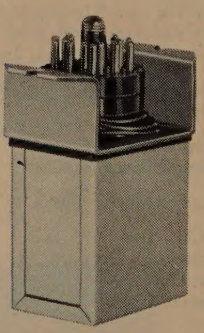
This new dust-tight enclosed relay is one of many outstanding CLARE contributions in the development of new and better relay components for industry. CLARE Sales Engineers are located in principal cities to consult with you on your relay problems. Call them direct or write: C. P. Clare & Co., 4719 West Sunnyside Avenue, Chicago 30, Illinois. Cable Address: CLARELAY. In Canada: Canadian Line Materials Ltd., Toronto 13.

Write for Bulletin No. 108





Neoprene gasket, closely fitted at factory to relay terminals, between base and cover, effectively occludes dust.



Plug is standard radio-type plug. Standard finishes are silver lustre lacquer for cover, cadmium for base. Retaining screws hold base securely to panel.

CLARE RELAYS

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For full details, write for Bulletin RT349. CORNELL-DUBILIER ELECTRIC CORPORATION, Dept. L50, South Plainfield, New Jersey. Other plants in New Bedford, Brookline and Worcester, Mass.; Providence, R. I.; Indianapolis, Ind., and subsidiary, The Radiart Corp., Cleveland, Ohio.

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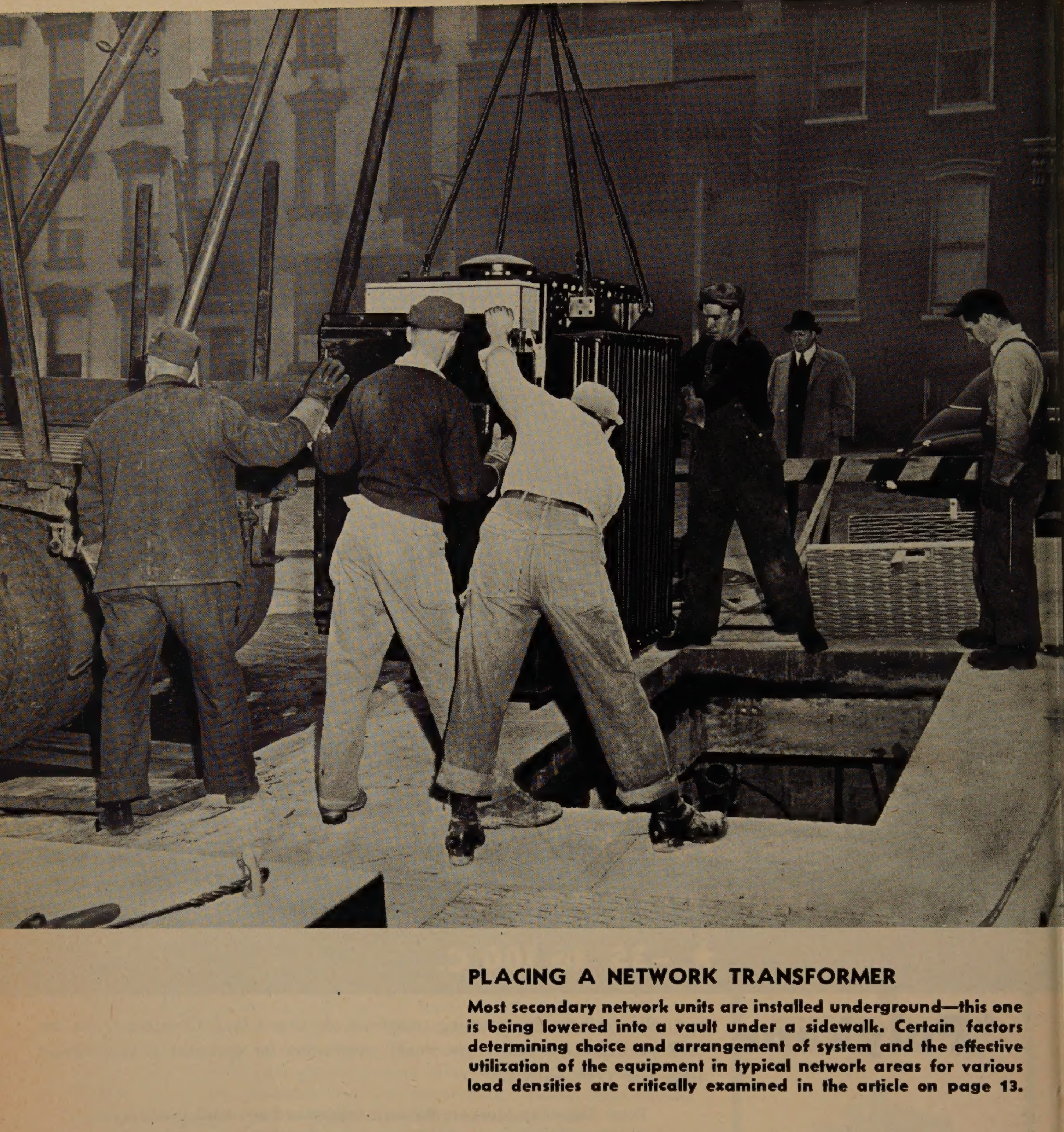
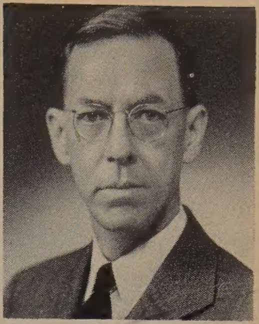


PLACING A NETWORK TRANSFORMER

Most secondary network units are installed underground—this one is being lowered into a vault under a sidewalk. Certain factors determining choice and arrangement of system and the effective utilization of the equipment in typical network areas for various load densities are critically examined in the article on page 13.

PRODUCTION OF ENRICHED NUCLEAR FUEL

A brief review of the advances that have been made in producing this fuel, directly and by the breeding process. Economic significance of its utilization in large-scale industrial application



K H Kingdon

By Dr. K. H. KINGDON
Knolls Atomic Power Laboratory
Operated by General Electric Company
For U.S. Atomic Energy Commission

THE first separations of uranium-235 from natural uranium were made just ten years ago in the Physics Laboratory of the University of Minnesota and in the Research Laboratory of the General Electric Company. These separations, although they involved only microscopic quantities of fissionable materials, were the first examples of the production of enriched nuclear fuel, and it seemed to me to be of some interest to describe the very great advances in the production of enriched nuclear fuel which have taken place during these last ten years.

The only naturally-occurring form of nuclear fuel is the isotope uranium-235, which occurs to the extent of one part in 140 of natural uranium. The bulk of natural uranium, of course, consists of the more abundant isotope, uranium-238, but it is only the rare U-235 which is fissionable enough by slow neutrons to serve as a basis for a nuclear chain reaction.

All of the large nuclear reactors which have been built so far use the naturally-occurring mixture of uranium isotopes, and it might therefore be asked why so much emphasis has been put on separating the rare fissionable isotope from the natural material. Back in 1940 the main interest in doing this was, of course, to establish firmly that U-235 was responsible for the fission phenomena which had been observed in natural uranium. It was essential to establish this fact on a firm basis before undertaking the development and construction of the tremendously expensive manufacturing plants which it was realized would be necessary to separate U-235 from U-238. But separation and concentration of the fissionable isotope were necessary for other reasons than for information. It was realized at that time that in order to build an atomic bomb, it would be necessary to separate and concentrate the U-235 in substantially pure form. It is also true that separation and concentration of the fissionable isotope are necessary for many of the peacetime applications of atomic energy; and, as a matter of fact, most of the new nuclear reactors, construction of which is being undertaken now by the Atomic Energy Commission, employ enriched uranium-235 as fuel. These are valid reasons for undertaking the separation of U-235 on a manufacturing scale.

The year 1940 seems quite a long time ago now. That was back in the days before so many physicists had acquired a taste for world legislation and extensive travel; that was also back in the days when a millicurie was a large unit of radioactivity and $100,000 was a whale of a lot of money for a scientific budget. The amount of U-235 that was separated in these early experiments was on an appropriately small scale to fit this modest background. The sample which we separated and sent to Columbia University to be tested with their cyclotron contained about one one-hundred-millionth of a gram of uranium-235; and if all these atoms had been fissioned in the tests at Columbia, they would have produced a total amount of energy equivalent to only about three ten-thousandths of a kilowatt hour. This was indeed a small-scale experiment compared with the millions of kilowatt hours of energy which are now liberated in the Hanford reactors.

Having settled that U-235 was the desired isotope, it was necessary to expand the scale of these first experiments by a factor of more than a hundred million in order to obtain usable amounts of this fissionable isotope. This expansion on such a heroic scale was undertaken by the Radiation Laboratory of the University of California for the Manhattan Engineer District and resulted in the creation of the huge electromagnetic isotope separation plant at Oak Ridge. This plant was based on the same fundamental scientific principles as the pioneer separation of the isotopes with the mass spectrometer; but, of course, a tremendous amount of research and development was needed to bring about the expansion to such a large scale of operation. The Oak Ridge electromagnetic plant operated successfully and produced the uranium-235 which was used in some of the early atomic bombs in 1945.

Back in 1940, vigorous experimentation was proceeding on other methods of separating uranium isotopes. Consideration was given to a cyclotron method in which the familiar resonance effect which involves the mass of an electrically charged atom and constitutes the basis of the operation of a cyclotron could be used to separate isotopes of nearly equal mass. Consideration was also given to various chemical and ion exchange methods; but it was found, as expected, that

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This article is so paged that, without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—EDITOR

This article was presented by Dr. Kingdon as a talk at the General Electric *Science Forum* broadcast on March 15, 1950, from Station WGY, Schenectady, N. Y.—ED.

these work well only for atoms which are much lighter than uranium. Attention was also given to the familiar centrifugal phenomenon used in the cream separator. If a mass of gas or liquid is rotated rapidly enough, the heavier isotopes will be concentrated at the periphery and the lighter isotopes near the axis. This centrifugal method has the advantage over others in depending only on the difference in mass of the isotopes to be separated, so that it is as effective for heavy isotopes as it is for light. Some experimental work was done on this process, but it was never put into large-scale production. The phenomenon of thermal diffusion was also investigated as a means of separation. In this method a gas or liquid containing the isotopes which it is desired to separate is subjected to a large temperature gradient and, by a suitable design of apparatus, the heavier isotope may be collected at one end of the apparatus and the lighter at the other end. A large-scale plant for the separation of uranium isotopes by thermal diffusion in a liquid uranium compound was actually constructed and put into successful operation at Oak Ridge but has since been dismantled.

So far we have not mentioned the method of isotope separation which has proved to be best of all. This involves the diffusion of a gas through a barrier which is riddled with tiny holes of a size comparable with the distance which the gas molecules move between collisions with each other. The lighter atoms penetrate the barrier slightly more rapidly than do the heavier atoms, so that the lighter isotope is somewhat concentrated in the gas after passing through the barrier. The successful development of this gas diffusion method culminated in the construction of the huge gas diffusion plant at Oak Ridge which has been in successful operation for several years at an ever-improving output. This gas diffusion plant has proved so successful that the electromagnetic plant at Oak Ridge has been taken out of operation, except for the use of a small part of its facilities for the production of separated stable isotopes of various other elements for use in research.

This brings up to date the story of the production of enriched nuclear fuel by the separation of uranium-235 from natural uranium. There is, however, another method of producing enriched nuclear fuel which may be of even greater importance for the future. This method consists in the production of artificial fissionable isotopes, such as plutonium-239, in a nuclear reactor. This isotope is produced by the action of neutrons on uranium-238; and since U-238 is 140 times as abundant in nature as U-235, it is clear that artificial fissionable materials will probably constitute the great bulk of the world's future supply of nuclear fuel. Plutonium-239 is now being produced in the nuclear reactors at Hanford, and the neutrons which make its production possible come from the uranium-235 which is consumed in these reactors. In the years to come, as our stockpile of plutonium-239 is built up, it should be possible to run a true breeding process, as it is called, in which the reactors burn plutonium-239 as fuel and produce larger quantities of plutonium-239 from the uranium-238 which is fed into the reactors for this purpose. This breeding process appears to be a secure foundation for a large atomic power industry in the future. The reactor which the Knolls Atomic Power Laboratory will build near Schenectady is designed as an experimental atomic power plant which will give information about both power production and breeding.

The development of useful power appears to be the only large-scale industrial application of atomic energy. In spite of much that has been written, the importance of this development probably rests hardly at all on the possibility of reduced cost for power, since even if fuel cost nothing, the price of power to the average consumer would hardly be reduced below 75 percent of the present figure. Instead it appears that the significance of atomic power is based on the following facts:

(1). Through the employment of breeding, fissionable material may become a substantial addition to the world's supplies of fuel. This statement can be supported by general considerations based on the abundance of the elements and on the ratio of the energy obtainable per atom of fissionable fuel to that obtainable per atom of conventional fuels.

(2). The nuclear fuel supply is based on an entirely different part of the national economy than is the supply of coal. By far the greater part of the cost of nuclear fuel comes from the refining and metallurgical industries above ground, and there is relatively little cost from mining operations or from transportation.

(3). The small bulk of nuclear fuel makes it suitable for special applications such as shipboard power plants or for use in remote locations.

(4). National policy at present demands the production of substantial quantities of fissionable material for stockpiling and for military applications. If the energy involved in this production could be converted to useful power, an appreciable reduction in the cost of the fissionable material might result.

The Atomic Energy Commission, through its contractors, is putting a large effort into the development of atomic power plants for both military and industrial uses, and it is to be expected that substantial progress will be made during the next few years.

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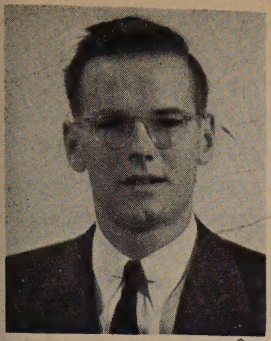


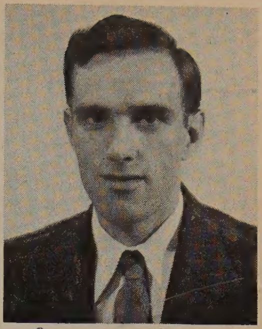
Norman M. Neagle

SECONDARY NETWORKS: PRIMARY-SYSTEM COSTS

How the primary voltage chosen to feed the transformers in a low-voltage network affects the total cost of the installation. Analysis indicates that the 15-kv class is usually best

By N. M. NEAGLE and R. W. SWARTHOUT

Central Station Engineering Divisions, Apparatus Department
General Electric Company



Raymond W. Swarthout

LOW-VOLTAGE a-c secondary networks provide a high degree of service continuity and are easily adjusted to areas expanding in size and load density. Such a condition is found in most present-day commercial districts.

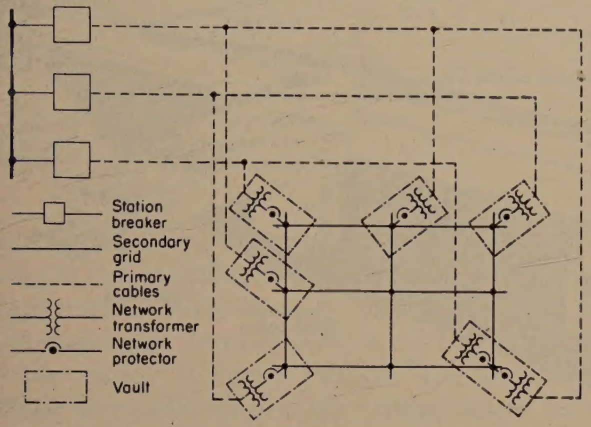


Fig. 1. Elements of a secondary network

Once the decision to consider the installation of such a network has been made, selection must be made of the voltage at which the power is to be carried throughout the area to the primaries of the network transformers. The choice of this primary voltage will generally be governed by the cost of installing the network and by the power system voltage available near the network.

Careful analysis of the effects of primary voltage on the cost of low-voltage networks indicates that the 15-kv class is ordinarily the most economical. The study from which this conclusion was deduced gave consideration to the network costs in three parts:

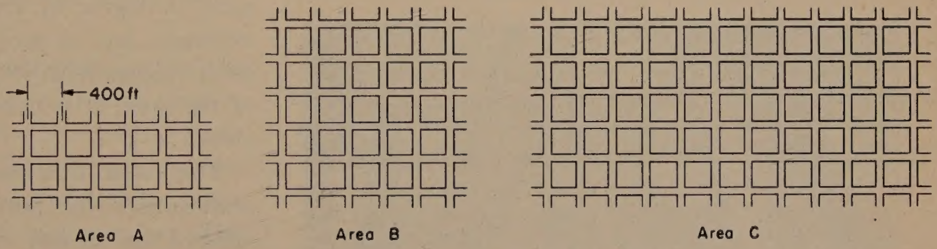
(1). The costs within the secondary network area
(2). Substation costs and
(3). Subtransmission costs to the area.

Basic Principles of Network Operation

Elements of the type of distribution system covered in this article are shown in Fig. 1. The whole system is called a secondary network. All loads, large and small, are fed by a solid secondary grid of cable. The secondary grid is supplied at various points by transformers. A minimum of three primary cables is commonly required to supply the transformers. These cables are connected to the different transformers in such a manner that no two transformers close to each other are supplied by the same feeder. Therefore, no two adjacent transformers would be taken out of service by a primary-cable outage.

The network protectors, which are components of the equipment, trip on reverse power flow and reclose automatically when power again will flow into the secondary grid, thus providing high continuity of service to the network loads. In the event of a secondary fault, the protectors will not open, but will allow the fault to burn clear or be sectionalized by limiters, thereby minimizing the number of consumers affected.

Fig. 2. Typical network areas analyzed in this article. Area *A*, at left, is six blocks by three blocks. Area *B*, center, is six blocks square. Area *C*, right, is six blocks by twelve



Over 300 such systems are used in cities in this country and abroad, as well as in some industrial and military establishments. Although a few secondary networks are installed overhead, the vast majority are underground in growing commercial areas and will be the subject of consideration here.

SECONDARY NETWORK COSTS

For study, a very simplified area (Area *A*, Fig. 2) was chosen and then expanded in both size and load density. To simplify the analysis, the load was assumed to be distributed evenly throughout the area, thus al-

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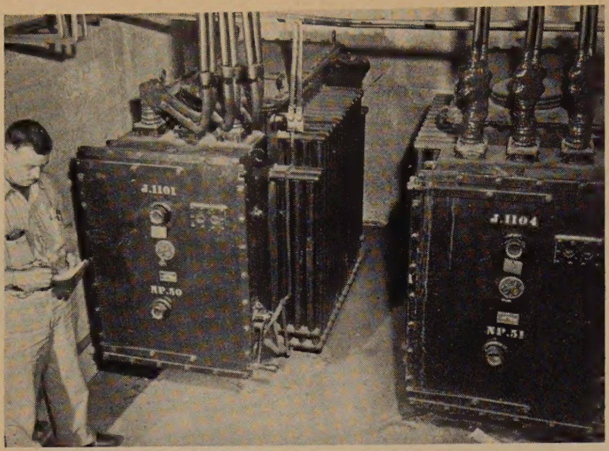


Two network transformers in a vault with all connections made. The primary cable, which enters at the far end, cannot be seen. The low-voltage cables are connected at the near end

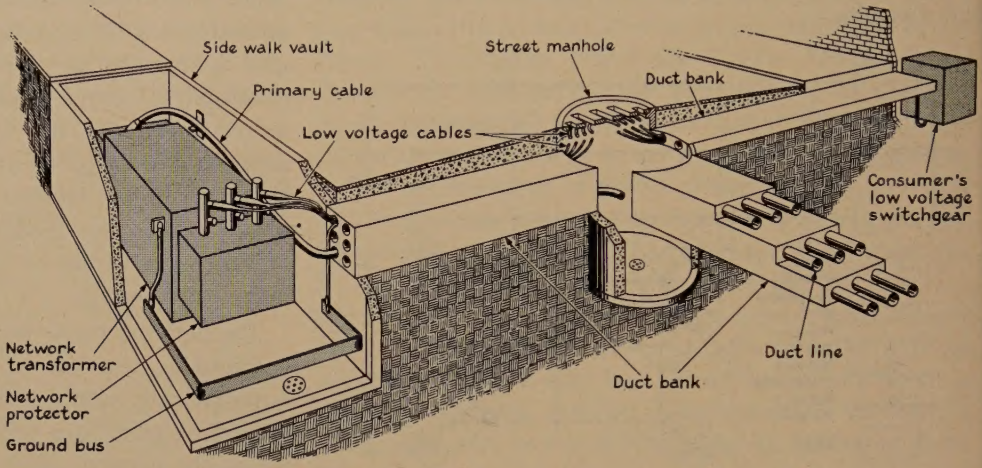
lowing symmetrical placement of the network transformers. The area is six blocks long by three blocks wide, including the half blocks picked up on all four sides of the network.

Network A was studied at a load density of 30,000 kva per square mile and was then expanded to network B, which is six blocks by six blocks. Network B was then examined at densities of 30,000, 60,000, and 120,000 kva per square mile and afterward expanded to network C which was double the previous area, or twelve by six blocks. Next, network C was analyzed at a density of 120,000 kva per square mile. All blocks were considered to be 400 ft long from center of street to center of street.

In making the study, the objective was a dual one: to endeavor to have the primary-feeder layouts comparable in degree of area coverage at different primary voltages, and to seek the most economical layout for each voltage with respect to the ultimate development of the area. It is believed that a fair balance has been struck.

The cable loadings, cable cost and associated installation costs, network unit, and vault costs considered are shown in Table I. The 500-kva network unit cost includes the high-voltage terminal chamber, high-voltage switch, 1600-amp low-voltage network protector, and a vault charge of $6000 per transformer for the 5-, 15-, and 23-kv primary voltage classes. The vault charge is raised to $8000 for the 34.5-kv class, at which point there is considerable increase in the size of transformer and the high-voltage switch.

The cost of the installed network was broken down into three parts as termed in Fig. 3 and shown by the curves in Figs. 4 through 8. The first curve is that of installed network unit costs. The second curve shows costs of the main cable, which is within the network area and which is necessary to cover the area and have the feeders within reasonable distance of all transformers. The third curve is the installed cost of stub feeder cable from the main cable run to the trans-



Cutaway drawing of an underground secondary network system showing components and their location

TABLE I

CABLE AND CABLE INSTALLATION COSTS

Voltage Class (Kilovolts)	Normal Loading (Kva)	Duct Cost Per Cable (Per ft)	Installation* Cost Per Cable (Per ft)	Cost of Cable (Per ft)	Total Cost Per Cable (Per ft)
5	2000	$1.00	35¢	$3.03	$4.38
15	6000	1.00	50	3.18	4.68
23	9000	1.00	60	3.90	5.50
34.5	15,000	1.00	75	5.14	6.90

* Installation cost includes drawing the cable into duct, splices, terminations, etc.

Note: A charge for digging the duct trench must be added to the total cost per cable listed above. This charge is divided equally between the primary and secondary at $8 per feet each, where there is a maximum of four primary cables. If more than four primaries are needed at a location, an additional charge of $16 per foot is made against the primary for additional trench.

NETWORK UNIT COSTS INSTALLED IN VAULT

Voltage Class (Kilovolts)	Cost Per Network Unit
5	$12,800
15	13,700
23	15,000
34.5	18,000

A network unit consists of a 500-kva transformer with a 1600-amp protector.
All equipment costs used in these tables and charts are estimated costs based upon General Electric Company prices at the time of writing. They do not purport to be authoritative or to reflect charges of other manufacturers.

formers in the area. The fourth curve is the sum of the first three and is the total installed network cost within the area. The costs of secondary cable, duct, and installation were neglected in this study. It was assumed that these would be equal for a given area and load regardless of primary voltage selected.

Examination of the curves in FIGS. 4 through 8 show very interesting trends in cost for the areas and densities studied. At load densities lower than 30,000 kva per square mile all components of network cost increase with increase in primary voltage, with the greatest increase in the cost of transformers. Therefore, as might be expected, the 5-kv primary-voltage class is the most economical within the area for low load densities. However, as load density and area increase, the cost of stub feeder cable to pick up the transformers remains fairly constant with voltage, and the cost of main cable drops sharply in the 15-kv class and then rises slowly at higher voltages. The transformer cost goes up rapidly for primary voltages above 15 kv. Therefore, in the 15-kv class, at high load densities the drop in main-cable cost overshadows the slight rise in cost of transformers.

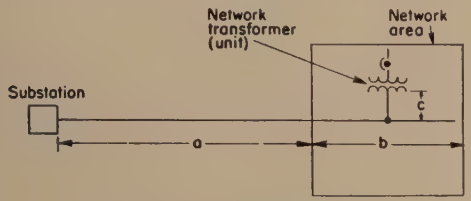


Fig. 3. Primary cable terminology

a: Subtransmission cable
b: Main cable
c: Stub feeder cable

The factor most prominent in raising the cost of the 5-kv class primary system for the high-load-density area is the increased number of cables required to carry the load. Therefore, a large number of main feeders must be placed throughout the area, and that incurs the expense of additional ductwork and trenches. The high cost of primary systems above the 15-kv class continues for the high-load-density area because of the steep rise in the cost of transformers. Also, the cost of installed cable remains high despite the fact that the cable cost per foot per kva decreases steadily. This is the result of not using the full rating of these cables economically. To load the cables to rating would require so few feeders in the area that the loss of a feeder would de-energize a large part of the transformer capacity, thus making the addition of extra transformers on all feeders necessary for emergency conditions.

Because low-voltage networks are suited for growing areas having fairly high load densities, it is assumed that the area may at some time have a heavy load density. For this reason, when considering the costs within the network area, it can be concluded that the most economical primary voltage is in the 15-kv class.

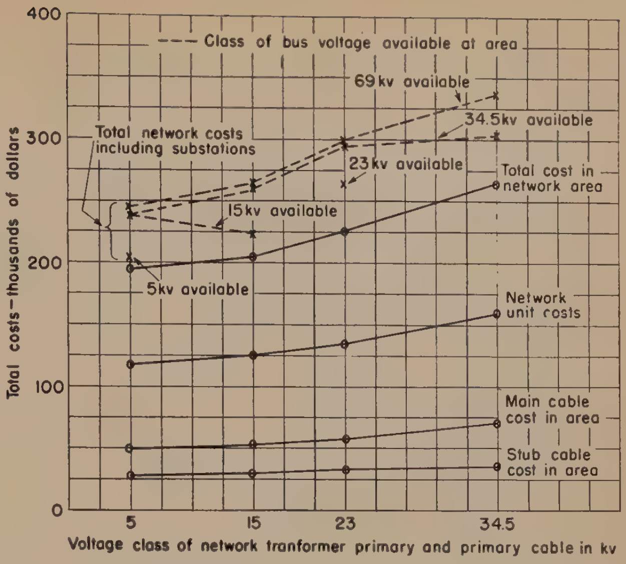


Fig. 4. Cost components of network *A*. Load density is 30,000 kva per square mile, with a total load of 3000 kva

SUBSTATION COSTS

Among the costs associated with the installation of a low-voltage network is that of substation equipment necessary to control the primary feeders to the network area and to transform the supply voltage from that available to that desired for the network primary. Since, in most cases, both a generating-station bus and substations will be in or near the network area, voltage classes of 5, 15, 23, 34.5, and 69 kv were considered available to serve the networks studied. These sources were assumed to have the necessary reliability for supplying a network and to provide power at the same cost for the different voltages considered.

A network transformer in place in a vault under a sidewalk. An adequate amount of room is left for later connection of cables

Substations were chosen and their cost estimated for each of the areas and load densities studied, assuming that power in the following voltage classes was available at the area:

5 kv for all 5-kv primary systems
15 kv for all 5- and 15-kv primary systems
23 kv for the 23-kv primary system
34.5 kv for the 5-, 15-, and 34.5-kv primary systems
69 kv for the 5-, 15-, 34.5-kv primary systems.

These substation costs were then added to the total cost of the network within the area and also plotted in Figs. 4 through 8.

Examination of the substation costs shows that where a transformation in voltage is necessary, the substation costs are essentially constant regardless of voltage. This is true when the percentage difference in substation cost is based on the over-all network cost. In these cases, the cost of substations will not greatly affect the conclusions reached when considering networks; and the 15-kv class will be still the most economical for the network. However, where a bus is available at the same voltage as the primary distribution in the area, the substation costs are low, since only switchgear is needed, and will have some effect on the over-all economic choice.

By reference again to Figs. 4 and 5 it will be seen that at the lower load densities the 5-kv class primary distribution has an economic advantage, particularly when a 5-kv class bus is available. At medium load densities (Fig. 6), if it is necessary to make a transformation to either the 5- or 15-kv class, the 15-kv class primary distribution is of slightly lower cost. If both the 5- and 15-kv classes are available, the 15-kv class is again of lower cost. Also, at medium density where a 23-kv class bus is available, it would be less costly to use 23-kv class primary distribution than to transform to lower voltage. At the larger load densities (Figs. 7 and 8), the most economical primary distribution voltage is always in the 15-kv class regardless of voltage available at the area (with the possible exception that it might be desirable to use a voltage in the 23-kv class throughout if no other voltage were available).

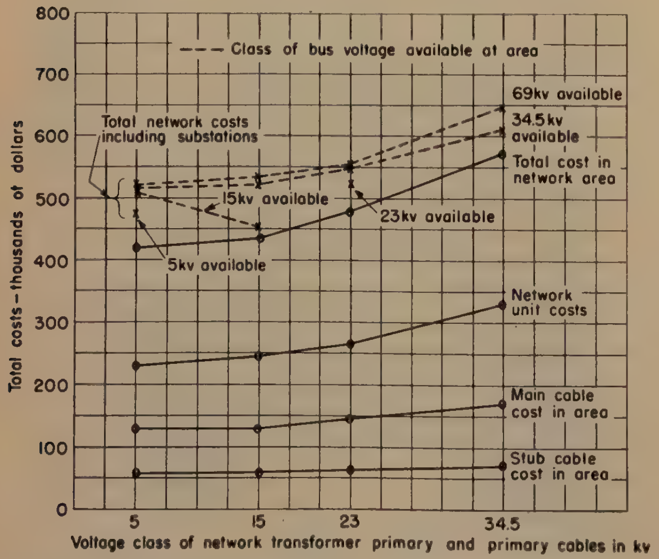


Fig. 5. Cost components of network *B*. Load density is 30,000 kva per square mile, with a total load of 6000 kva

The continuation of a 23-kv class system should be considered carefully since it is diminishing in application. Also, the use of primary feeders of the 23-kv class or of a higher voltage often requires a special combination reactor and grounding transformer to compensate for cable charging current and to limit voltage rise under fault conditions. These costs were not included in this study.⁽¹⁾

In general, when the total cost of an a-c network is considered, including substation charges, a primary distribution voltage in the 15-kv class will prove economical in the long run for a growing area. This confirms the conclusions reached concerning the cost within the area itself. In any specific study, the cost of power at the different voltages, the adequacy of available sources, etc, must be taken into account and may also cause the 15-kv class to be more desirable than a 5-kv class primary at lower load densities.

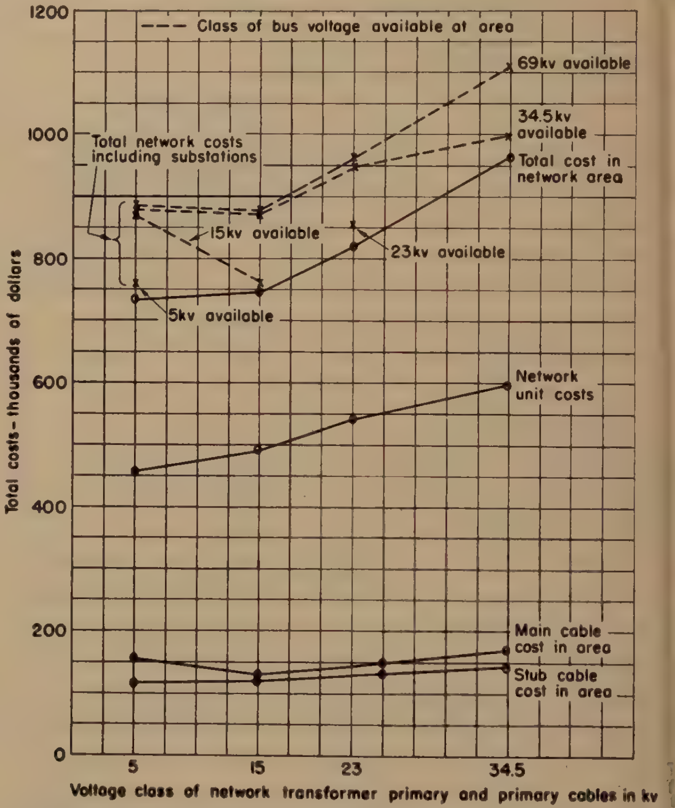


Fig. 6. Cost components of network *B*. The load density is raised to 60,000 kva per square mile, and the total load is 12,000 kva

SUBTRANSMISSION COSTS

The last cost to be considered is that of distance subtransmission to the network area.⁽²⁾ Voltages in the 5-, 15-, 34.5-, and 69-kv classes available to serve the network are now considered to be at some point remote from the area, and power is assumed to cost the same dollars per kva at all voltages. The question of economical subtransmission voltage becomes one of balancing the savings in cables by use of higher voltages and fewer circuits against the savings with a lower voltage and more circuits by going through the network area without a transformation. The economical voltage at which power should be brought to the area is then a function of the total kva to be transmitted and the distance of transmission. This is particularly evident in Figs. 7 and 8, since consideration of network and substation costs demonstrates that it then becomes economical to always transform the voltage to the 15-kv class at the network area.

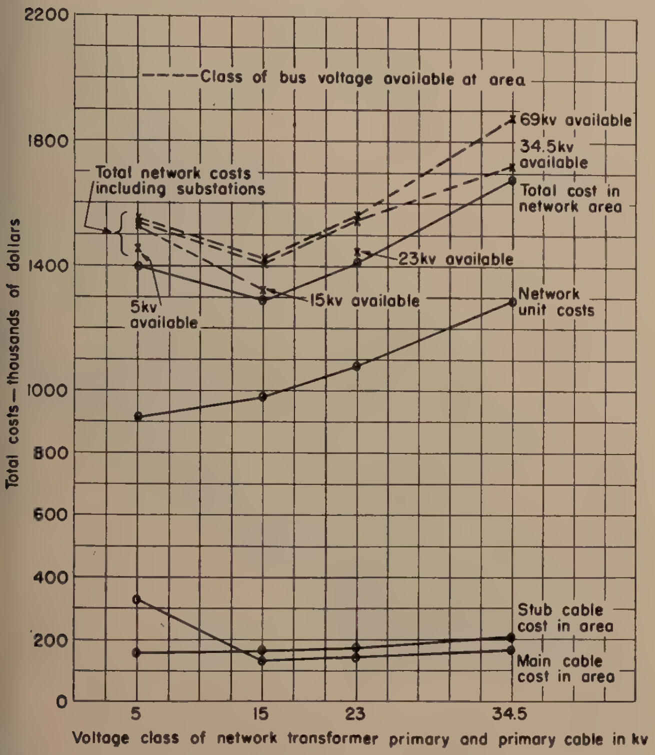


Fig. 7. Cost components of network *B*. The load density is again raised to 120,000 kva per square mile, and the total load is now 24,000 kva

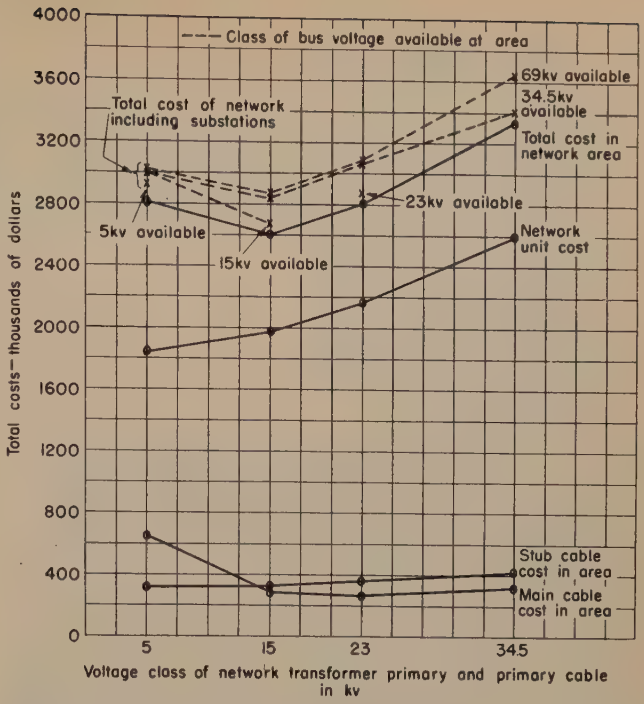


Fig. 8. Cost components of network *C*. Load density is 120,000 kva per square mile, with a total load of 48,000 kva

Referring to the areas used in this study, for networks *B* and *C* at load density of 120,000 kva per square mile, where it was proved to be economical to always step down to the 15-kv class for area coverage, the choice of distance subtransmission voltage classes is 15, 34.5, or 69 kv. At lighter densities and smaller areas, the choice

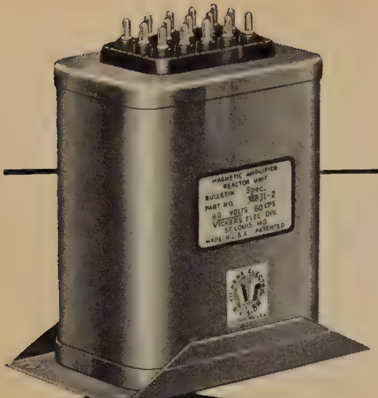
(Continued on next page)

TABLE II

ECONOMICAL DISTANCES OVER WHICH POWER IN VARIOUS VOLTAGE CLASSES CAN BE TRANSMITTED TO THE NETWORK AREA FOR USE AT 15 KV

			15-Kv Class			34.5-Kv Class			69-Kv Class		
Area (Fig. 2)	Load Density (Kva per sq mi)	Total of Individual Peak Loads (Kva)	Cost per Circuit Mile(a)	Number of Circuits	Maximum Economical Subtransmission Distance (Miles)	Cost per Circuit Mile(a)	Number of Circuits	Maximum Economical Subtransmission Distance (Miles)	Cost per Circuit Mile(a)	Number of Circuits(b)	Maximum Economical Subtransmission Distance (Miles)
					By Underground Cable						
C	120,000	48,000	$20,000	8	2.5	$31,000	3	None	$48,000	2	(c)
B	120,000	24,000	20,000	4	4.1	31,000	2	None	48,000	2	(c)
B	60,000	12,000	20,000	3	None	31,000	2	(c)	48,000	2	(c)
					By Overhead Transmission						
C	120,000	48,000	$12,000	8	2.8	$12,000	3	4.25	16,000	2	None
B	120,000	24,000	12,000	4	3.1	12,000	2	None	16,000	2	(c)
B	60,000	12,000	12,000	3	8.7	12,000	2	None	16,000	2	(c)

(a) Trench charge not included for underground cable or right-of-way charge not included for overhead cable.
(b) At least two circuits are used for continuity, regardless of loading.
(c) For loads considered, these circuits can not be loaded economically.



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SECONDARY NETWORKS COSTS

(Continued from preceding page)

is primarily the 5- or 15-kv class for distance subtransmission and area coverage unless long subtransmission distances are necessary.

For example, in network *C* at a load density of 120,000 kva per square mile, the total peak load is 48,000 kva. Assuming area coverage in the 15-kv class, a distance subtransmission voltage in this class would allow substation savings of $169,000 (Fig. 6). However, eight circuits would be necessary at $20,000 per circuit-mile for cable, or the total cost for distance coverage would be $160,000 per mile. Using the 34.5-kv class for distance coverage would not make possible the substation savings, but only three circuits would be necessary at $31,000 per mile or a total of $93,000 per mile. Hence, by using a higher voltage, it would be possible to save $67,000 per mile of distance coverage.

Therefore, at 2.5 miles the over-all cost of the network installation would be equal for 15- or 34.5-kv class subtransmission voltages. If distance coverage were greater than 2.5 miles, it would prove economical to use the higher voltage for distance subtransmission and step down at the network border. Since the networks are usually located near the center of at least moderate-size cities, a generating station or a substation should be nearby, and it appears that the 15-kv class would be a prominent distance coverage voltage.

This type of analysis, as applied to other voltages and areas by the authors, is shown in Table II. The possibility that overhead transmission could be used outside the network area was considered and listed in Table II, where it will be seen that the results are not greatly different from those for cable transmission. For the loads studied, it seemed impractical to consider anything above 34.5 kv.

SUMMARY

To summarize the conclusions reached in this study, there appears to be a definite economic advantage in the use of the 15-kv class as the area coverage primary voltage for an a-c secondary network. Its use allows the minimum of duct and installation charge without a high charge for insulation. Also, the cable loadings are such that the loss of one primary feeder does not de-energize more than usually allowable transformer capacity for the average-size network.

Block power transmission to the area should be done at the most economical subtransmission voltage as dictated by the size of load to be carried and the distance it must be carried.

REFERENCES

(1) "New Reactors Limit Voltage Rise on Network Cables," by C. A. Woodrow, *Electrical World*, vol. 100, Dec. 17, 1932.

(2) "Economics of Subtransmission," by D. K. Blake, C. A. Woodrow and O. B. Falls, Jr., *Electrical World*, vol. 130, Sept. 11, Sept. 25, and Oct. 9, 1948.

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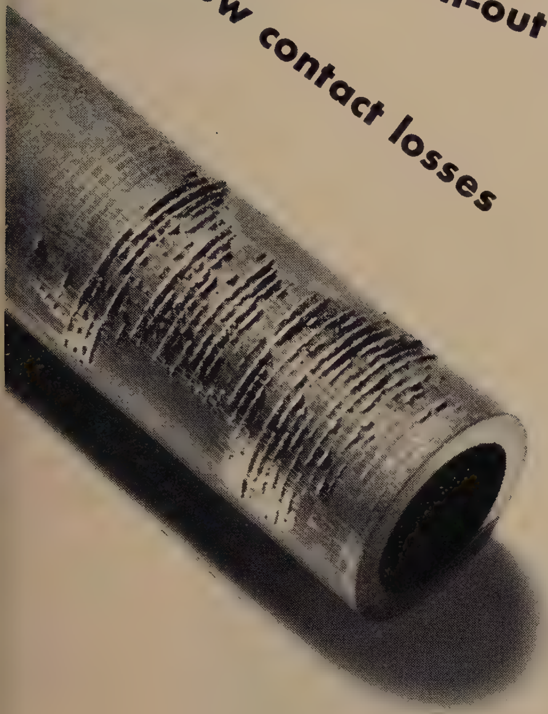

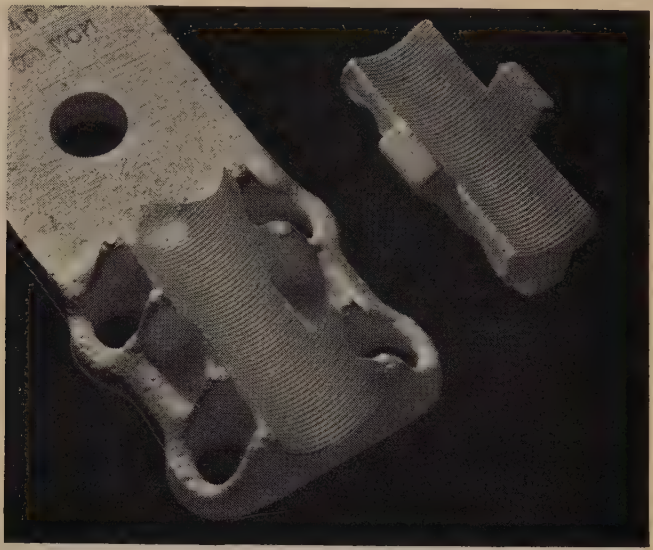

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GENERAL ELECTRIC

856-54

SURGE PROTECTION: A-C ROTATING MACHINES

E. M. Hunter

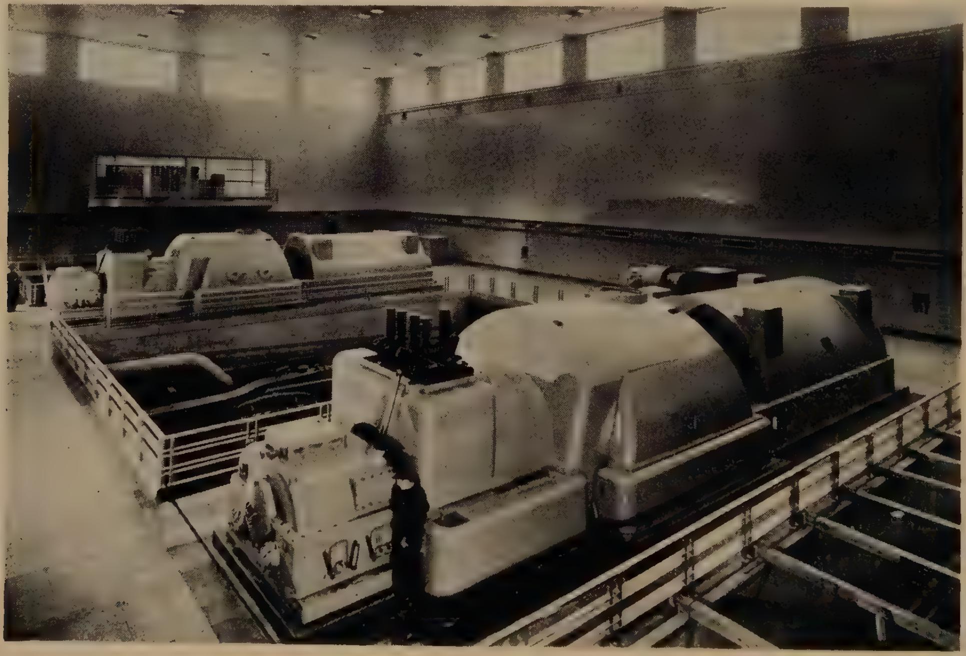
How modern practices have been developed for furnishing that protection to machines which are connected directly, or through transformers, or in both ways to exposed overhead lines. Answers to questions that frequently arise

N.E. Dillow

By E. M. HUNTER and N. E. DILLOW
Central Station Engineering Divisions, Apparatus Department
General Electric Company

THE response of rotating a-c machines to lightning transients was first described in two papers presented before the AIEE in Toronto in 1930 by Boehne(1) and by Beck and Fielder.(2) As twenty years have passed since the recognition of the need for surge protection for that type of machine, it appears desirable first to review the present state of surge protection of the machines.

The original papers pointed out the vulnerability of machine installations to lightning and the need for a combination of protective capacitors and arresters to control the transient distribution of voltage in the machines so that various parts of the machine windings would not be overstressed. The capacitors connected at the machine terminals could be likened in effect to the shielding of transformer windings, the technique of shielding having been introduced only a few years previously, in 1927.



Steam-turbine-generator sets such as these are surge-protected. Protective equipment is in pit beneath generator

The methods of protection suggested in 1930 were for machines connected directly to exposed overhead circuits. There was still much to be learned concerning the passage of lightning surges through transformers. In 1932, Paluev and Hagenguth(3) presented a paper which showed that power transformers were not the barriers to lightning transients they were once thought to be. Hence, it became evident that rotating machines having transformers between them and the exposed overhead circuits also require protection.

Since those early papers, the economy and practicability of providing protection with capacitors and arresters have been studied, and the practice has increased in the industry through the years. The acceptance is indicated in the survey of lightning protective equipment for rotating a-c machines made by the AIEE Lightning Protective Devices Subcommittee. This survey was published as AIEE technical paper No. 48-78,(4) and presented a cross section of modern central-station practice. While it is the analysis of the central-station protection problem that will be considered in

This article is so paged that, without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—Editor

this article, the same general principles are equally applicable to protection of large motors in industrial applications.

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(1)For numbered references see list at end of article.

The surge protection of machine windings presents two problems: first, the protection of the major insulation to ground by limiting the amplitude of applied surges or reflections within the machine windings; and second, the protection of turn insulation by reducing the steepness of wave fronts applied to or reflected within the machine windings. A combination protective scheme of capacitor and arrester provides the solution to the problems.

Central station applications fall into three general classes of circuit arrangement: (a) the unit system, with the generator connected to the system through a power transformer; (b) the generator connected directly to outgoing lines; and (c) the generator connected to outgoing lines both directly and through transformers. In all three classes, surge protection of the rotating machine can be justified where the outgoing circuits are exposed.

MACHINES CONNECTED THROUGH TRANSFORMER TO EXPOSED OVERHEAD LINES

One of the trends in design of central-station generating stations is that toward the unit system; that is, the generator and the step-up power transformer are a single unit, with no power circuit breaker at generator voltage. With this system the exposure to lightning is through the step-up transformer bank.

Most transformers used in this type of layout are connected wye-delta with the delta winding connected to the generator. Briefly, a surge on one phase of the wye (high-side) winding may be transmitted through the transformer both electromagnetically and electrostatically to the generator. The electromagnetic component appears on the generator side as a phase-to-phase voltage; that is, one of the low-voltage phases is raised to a positive potential above ground, the second to an equal, but negative potential, while the third remains at substantially zero potential. The electrostatic components of the surge voltage appearing on the delta side of the transformer are of the same polarity as the incoming surge; however, these are of very short duration and consequently have a low energy content. Analysis has indicated that suitable protection from the electromagnetic component will also be effective for the electrostatic components.

To better visualize the character of the surge voltages transmitted, cathode-ray oscillograms of them are presented in Fig. 1. These illustrate the measured transient voltages to ground at the three generator line terminals and at the neutral.(5) The generator utilized in the test was a 12,500-kva 6600-volt turbine-generator; the voltages resulted from the application of a 1×5.6 microsecond 10-kv crest positive wave to one phase on the high-voltage side of the transformer. These oscillograms show the various components of voltage and the division of the electromagnetic component. The neutral voltage resulted from the electrostatic component of the transmitted voltages that were attenuated and elongated as they passed through the winding. The surges, being of like polarity, did not cancel at the neutral as did the electromagnetic components. Other tests indicated that similar electromagnetic distribution of voltage was obtained with the transformer neutral grounded.

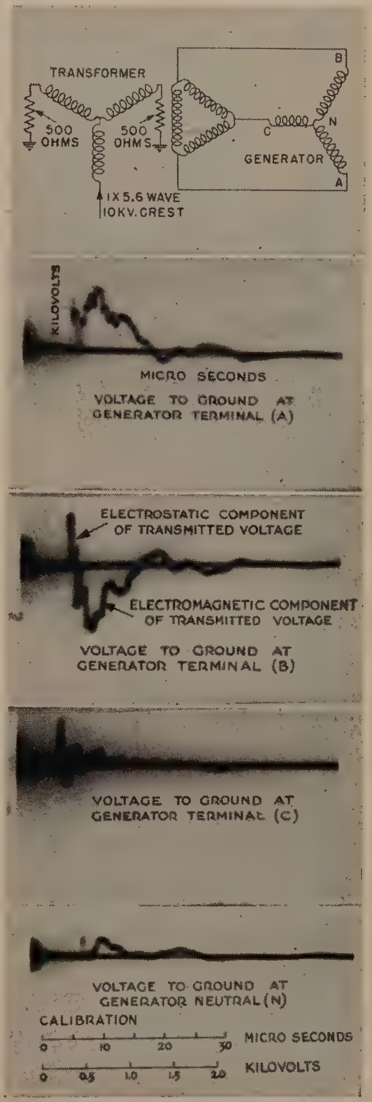

Fig. 1. Distribution of voltage, on the generator side of a wye-delta transformer, resulting from an impulse to one phase of the line side

The surge protective plan for the unit generating system is indicated in Fig. 2 and should consist of the following:

(1). Station-type lightning arresters installed on the high-voltage side of the power transformer. These arresters, properly installed, will limit not only the magnitude of the surge voltage reaching the transformer, but also the magnitude of the surges transmitted through the transformer to the low-voltage side.

(2). At the generator terminals, station-type lightning arresters and protective capacitors installed in as close a shunt relationship with the generator as is practicable. The arrester will limit the crest of the transmitted surges, and the capacitor will primarily absorb the electrostatic component of the transmitted voltage. It is to be noted that since the electromagnetic components of voltage are induced between phases and are of opposite polarity, the transient voltage at the generator neutral remains at substantially zero potential, and neutral protection need not be considered in this type of application, regardless of the method used to ground the machine neutral.

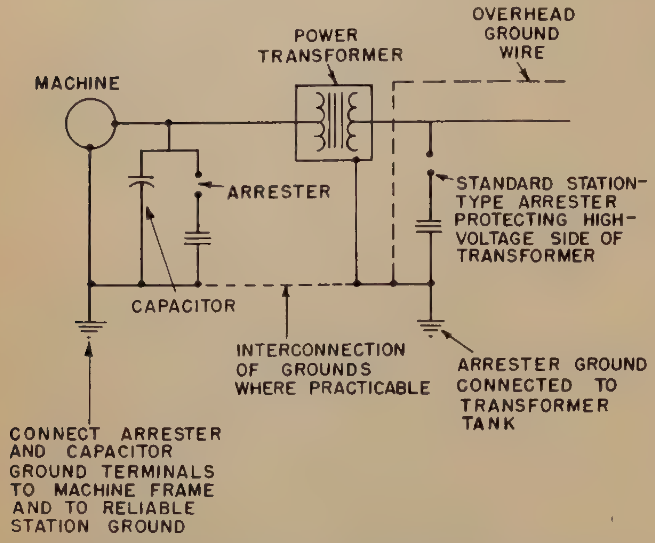
OVERHEAD GROUND WIRE
POWER TRANSFORMER
MACHINE
ARRESTER
STANDARD STATION-TYPE ARRESTER PROTECTING HIGH-VOLTAGE SIDE OF TRANSFORMER
CAPACITOR
INTERCONNECTION OF GROUNDS WHERE PRACTICABLE
ARRESTER GROUND CONNECTED TO TRANSFORMER TANK
CONNECT ARRESTER AND CAPACITOR GROUND TERMINALS TO MACHINE FRAME AND TO RELIABLE STATION GROUND

Fig. 2. Surge-protective plan for a unit generating system, connected through transformers to an exposed overhead line, uses station-type lightning arrester and shunt capacitor

The close connection relationship between the protective equipment and the generator cannot be stressed too highly. When so installed, the protective equipment will limit the surge-voltage stress between the winding and the machine frame, and will make the protection independent of the station ground resistance.

The selection of the protective equipment, especially the arrester, is directly associated with the manner in which the generator neutral is connected to ground. The ultimate in protection can be obtained if the grounded-neutral, or 80-percent-rated, station-type arrester is used, in which case the X_0/X_1* ratio at the terminals of the generator should be three or less. To obtain this ratio the neutral must be grounded through a low value of reactance, because, in general, direct grounding of the neutral is not acceptable, as outlined in the ASA Standards on Rotating Electrical Machinery No. C-50.

More frequently, the generator neutral in a unit system is grounded through some such device as a resistor, a distribution transformer, or a potential transformer. When the grounding is through any of these devices, the X_0/X_1 ratio is greater than three, and the ungrounded-neutral, or 100-percent-rated, arrester should be applied. The purpose in using any of these relatively high-impedance devices for grounding is to limit the damage at the point of fault if a ground should develop in the generator. In selecting the surge-protective equipment and the neutral grounding device, a decision must be made as to which feature shall take preference. If limitation of fault current is considered the most important, then the ultimate in surge protection is not possible. On the other hand, if the best in surge protection is desired, then the neutral must be effectively grounded through a low impedance, usually reactance.

The size of the protective capacitor in microfarads must also be determined. Early investigations of this problem indicated that 0.1 μf was sufficient for protecting the turn insulation, and 0.5 μf for preventing excessive neutral reflections, when the exposure was from directly connected overhead lines. For the unit system in the 15-kv class of equipment, however, a 0.25-μf capacitor is considered adequate for the usual application. On the other hand, if the transformer is wye-wye-connected or is an autotransformer, a total of 0.5 μf per phase is considered necessary to limit neutral reflections.

The application of arresters and capacitors as indicated in FIG. 2 will provide the best surge protection possible with present protective components.

MACHINES DIRECTLY CONNECTED TO EXPOSED OVERHEAD LINES

Many generating stations are not laid out on the unit system. If the generator is connected directly to the outgoing circuits, then (in addition to locating station-type arresters and protective capacitors at the machine terminals) line-type arresters should be installed 1500 to 2000 ft out in each line. The surge-protective plan for this type layout is indicated in FIG. 3.

The set of line-type arresters intercepts the incoming surges so that the protective equipment at the machine terminals does not have to handle high surge currents.

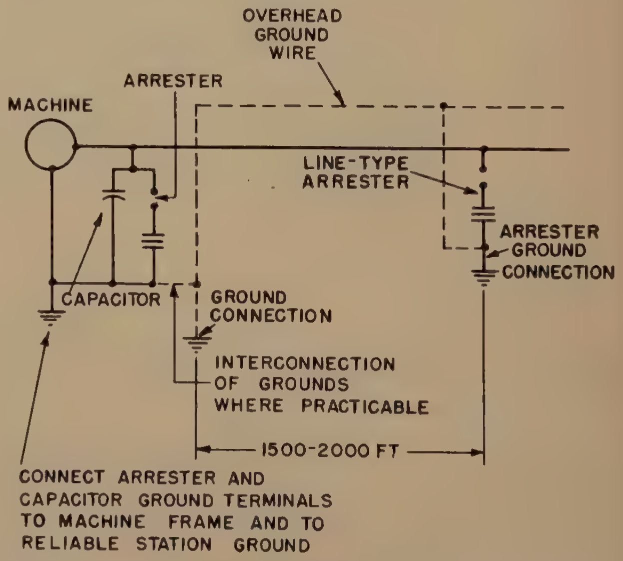
OVERHEAD GROUND WIRE
ARRESTER
MACHINE
LINE-TYPE ARRESTER
ARRESTER GROUND CONNECTION
CAPACITOR
GROUND CONNECTION
INTERCONNECTION OF GROUNDS WHERE PRACTICABLE
1500-2000 FT
CONNECT ARRESTER AND CAPACITOR GROUND TERMINALS TO MACHINE FRAME AND TO RELIABLE STATION GROUND

Fig. 3. Line-type arresters (in addition) are used for protection of machines directly connected to exposed overhead lines

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*X_0/X_1 is the ratio of the zero-sequence reactance to the positive-sequence reactance of the system as viewed from the point of arrester application. It is a convenient criterion for establishing the rating of arresters.

This arrangement allows a better protective level to be maintained at the generator.

It will be recognized that the possibility of direct strokes at or near the station dictates as much direct stroke shielding at the station as is practicable.

As previously stated, the selection of the arrester rating is determined by the manner in which the generator neutral is connected to ground. However, the protective capacitor must be adequate to limit neutral reflections. This requirement dictates the use of a 0.5-μf unit in all voltage classes of equipment.

In stations where there is more than one generator on a bus, it occasionally becomes desirable to selectively ground the neutrals of several generators, which will leave some generator neutrals ungrounded. For such an application it is desirable to have a set of arresters and capacitors on the generator side of the circuit breaker to limit any switching transients that might occur. With the generator neutral ungrounded, any multiple restriking in the breaker may produce overvoltages; these are highest on ungrounded-neutral systems. The arrester for this application is a limiter of overvoltage regardless of the cause of the surge—whether lightning, switching, or some other.

The application of arresters and capacitors as indicated in FIG. 3 provides the best surge protection possible for this rather difficult problem.

MACHINES CONNECTED BOTH DIRECTLY AND THROUGH TRANSFORMERS TO EXPOSED OVERHEAD LINES

When machines are directly connected to exposed overhead lines and also are connected by transformers to overhead lines, surge protection is accomplished by a combination of the two foregoing arrangements, as indicated in FIG. 4.

FREQUENT QUESTIONS AND THEIR ANSWERS

When working on any surge protective problem, certain questions concerning the application of the equipment repeat themselves. Following are some of the questions and answers pertaining to protection of rotating a-c machines.

QUESTION 1: With the demonstrable impulse strength of the rotating-machine winding being given as the crest of the 60-cycle high-potential test, how can protection be expected with the present-day arrester characteristics so close to this value?

Answer 1: Several factors must be considered when making a co-ordination study of this protective equipment.

First, there is considerable evidence that the impulse strength of the machine winding is somewhat greater than the crest of the 60-cycle high-potential test. How much greater than the crest value of this test cannot be definitely stated until further investigations are completed.

Secondly, the gap breakdown of an arrester is a function of the rate of rise of the applied voltage. Values of impulse voltage sufficient to start discharge are published for two rates of rise: the AIEE wave, which has a front with a rate of rise of 100 kv per microsecond per 12 kv of arrester rating, and the slower 1½×40 full wave. The gap breakdown on the slower wave is approximately 5 kv below that on the AIEE wave for a 12-kv arrester. With a capacitor in parallel with the arrester at the machine terminals, the rate of rise will probably be slower than the 1½×40 wave, with the result that the protection will be somewhat better.

Lastly, the field experience with this protective equipment has been quite favorable, a fact which is borne out in the AIEE Lightning Protective Devices Subcommittee survey of 1948, to which reference has already been made.

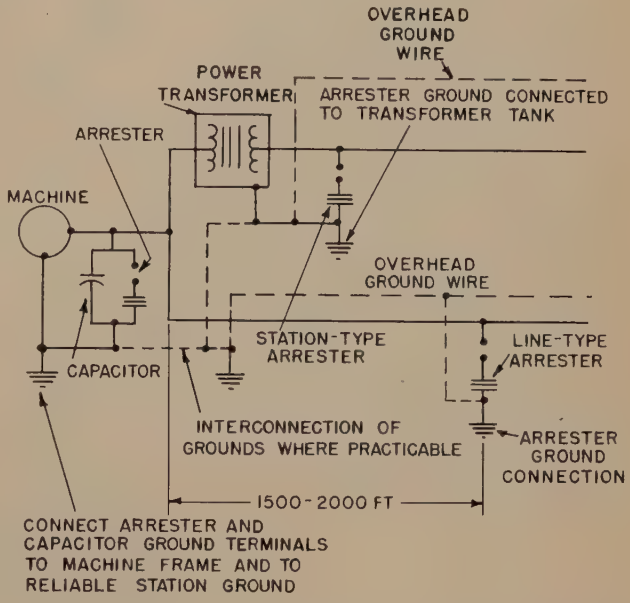
OVERHEAD GROUND WIRE
POWER TRANSFORMER
ARRESTER GROUND CONNECTED TO TRANSFORMER TANK
ARRESTER
MACHINE
OVERHEAD GROUND WIRE
STATION-TYPE ARRESTER
LINE-TYPE ARRESTER
CAPACITOR
INTERCONNECTION OF GROUNDS WHERE PRACTICABLE
ARRESTER GROUND CONNECTION
1500-2000 FT
CONNECT ARRESTER AND CAPACITOR GROUND TERMINALS TO MACHINE FRAME AND TO RELIABLE STATION GROUND

Fig. 4. Combination of the systems shown in Figs. 2 and 3 is used for protection of machines connected both directly and through transformers to overhead lines

QUESTION 2: With cable between the machine and the power transformer, is the capacitance of the cable sufficient to make protective capacitors unnecessary?

Answer 2: Cable capacitance is distributed; the cable will therefore act more as a surge impedance than as a lump capacitance for this application. If there are other cables leading off the bus, they may be considered the equivalent of shunt capacitance. In general, with a single cable between the transformer and generator, protective capacitors should be installed.

QUESTION 3: At what points in a generator winding is lightning most likely to cause a failure?

Answer 3: If the generator winding has a multi-turn coil, the turn insulation on the line-end coils usually gets the highest stress. Furthermore, the generator will be subjected to high reflected voltages if the exposure is through directly connected overhead lines, or through a power transformer which has other than a wye-delta connection, and unless the neutral is grounded through a resistance that is less than the surge impedance of the generator winding or through a reactance of 5 ohms or

(Concluded on following page)

less. Thus, in general, if lightning is suspected as being the cause of a machine winding failure, the line-end coils and the neutral are the two most likely points to look to for damage.

QUESTION 4: What causes an arrester to fail?

Answer 4: An arrester has a maximum permissible line-to-ground voltage rating. Just as long as the dynamic voltage across the arrester does not exceed this value, the arrester will operate satisfactorily. When a station-type arrester of modern design fails in a relatively sheltered application, such as is found in generating stations, the cause of the failure can almost invariably be traced to dynamic overvoltages in excess of the arrester's rating.

Voltages in excess of the maximum permissible line-to-ground voltage rating may not cause the arrester to fail if only momentarily applied and provided the arrester gap does not spark over. However, should some transient disturbance cause the gap to become conducting, the arrester may not reseal if the dynamic voltage is above this rating. Arrester failure will probably result.

The arrester voltage rating and the dynamic overvoltage on the system must be so co-ordinated that the maximum permissible line-to-ground voltage rating of the arrester is not exceeded; otherwise there is risk of arrester damage due to power overvoltage.

QUESTION 5: Should arresters with ratings higher than are normally chosen be used to minimize the possibility of arrester failure?

Answer 5: The protection provided by such an arrester is definitely questionable under the condition being considered; therefore the arrester should not have a higher rating than would normally be selected. The reason is that the protective level established by an arrester is proportional to the rating of the arrester; hence a higher rating would result in less protection. These factors must be weighed against each other.

QUESTION 6: Should the grounded-neutral, or 80-percent, arrester be used on a machine whose neutral is so grounded that the X_0/X_1 ratio is greater than 3?

Answer 6: The use of such an arrester should provide better surge protection because of the increased margin. However, should a ground fault develop either in the machine or external to it, the overvoltage impressed on the arrester may cause it to fail. If this should occur, what originally started out to be a single line-to-ground fault might develop into either a phase-to-phase or a three-phase fault. It is generally felt that, because of this risk, such an application cannot be rationalized.

QUESTION 7: Should a special short-circuit protective device be used with surge-protective equipment?

Answer 7: It is axiomatic that one protective device should not be used to protect another protective device. The most common device that could be used as a short-circuit protective device is a fuse. If it were used, however, there would be no way of knowing except by inspection whether the fuse is intact. (In the usual application of a fuse, its blowing is evidenced by loss or curtailment of service, but that indication is not given by a fuse in the application being considered here.) Furthermore, there is a good possibility that the fuse would be open at just the time when the surge-protective equipment would be most needed.

It is nevertheless desirable that the surge-protective equipment be so located in the system that trouble will be detected and cleared by other existing protective devices on the machine circuit.

QUESTION 8: Is the installation of surge-protective equipment justified?

Answer 8: During the past few years several generators apparently failed because of lightning surges. Most of these failures were in hydroelectric installations. There are a number of case histories where such failures ceased after protective equipment was installed. To be sure, in such cases the evidence of the effectiveness of the protective equipment is not positive, because it is always possible that further failures would not have occurred anyway. On the other hand, the number of cases in which failures have ceased is sufficiently large that it is felt that effectiveness is proved.

A further check on the effectiveness of the protective equipment is the AIEE survey that was made in 1948, which has been referred to earlier. While it is not conclusive, some 30 out of 54 of the companies replying were definitely in favor of the use of such equipment. Five companies reported 50 to 90 percent fewer failures, and nine reported no failures at all after installing protective equipment.

For new installations, the trend in industry is to install surge-protective equipment where there is exposure to lightning at the station. Therefore, to the question, "Is the installation of surge-protective equipment justified?" the answer for the usual application is "Yes."

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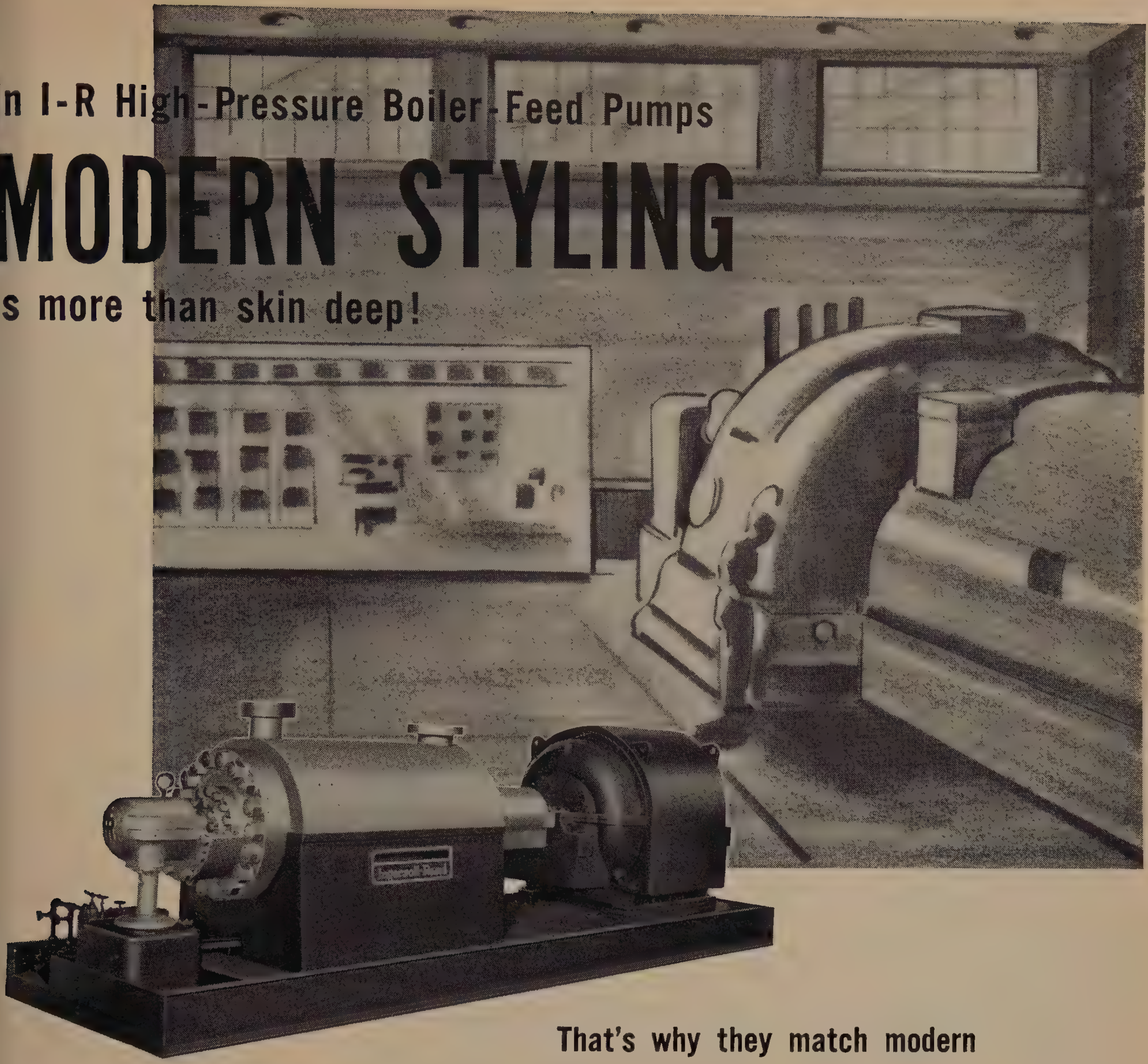

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PROTECTIVE ATMOSPHERES IN INDUSTRY . . Part XVI

Summary of procedures for correcting conditions that sometimes lead to undesirable effects. Numerous practical suggestions for applying remedies

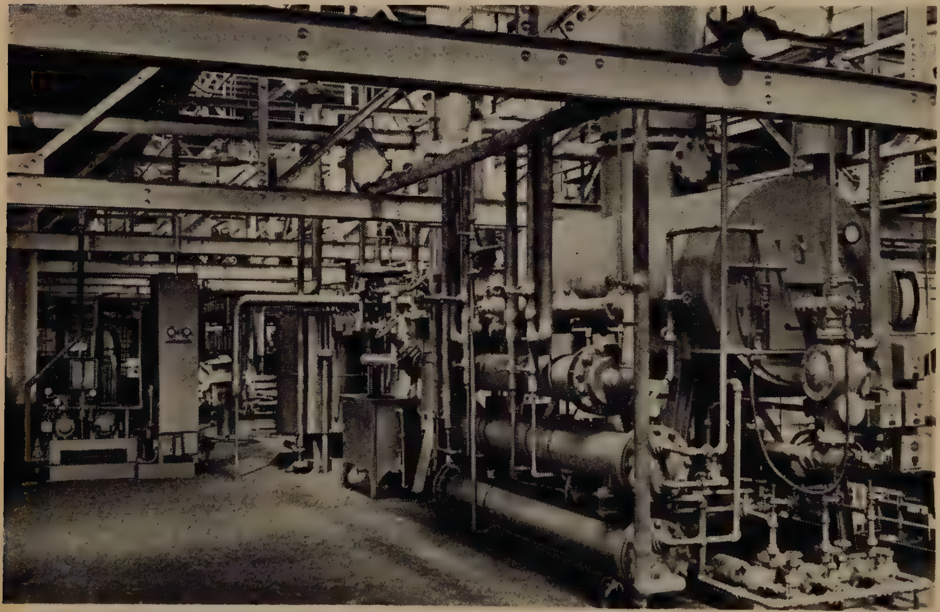
By A. G. HOTCHKISS and H. M. WEBBER
Industrial Heating Divisions, General Electric Company

IN THE operation of protective atmosphere equipments, things sometimes go wrong and undesirable results are obtained. Discoloration of the work being treated in furnaces is the most common ailment, and decarburization is next. Once the cause of the difficulty is found, correction of it is often a simple matter. To aid in putting a finger on troubles, Table XXI has been prepared. It is a summary of what to look for and what to try if things go wrong.

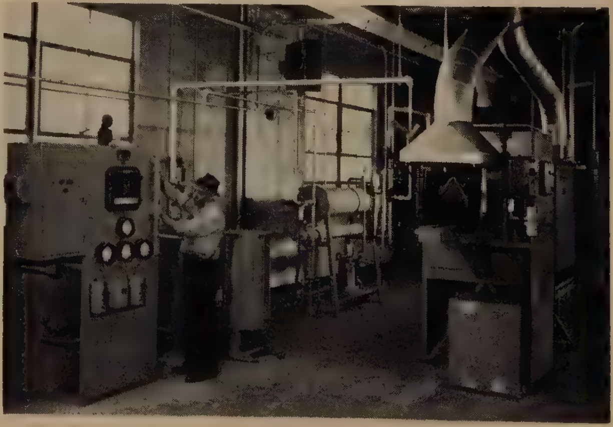
Troubles often can be typed and catalogued; some of the more common ones are listed in italics at the left side of Table XXI. If the trouble is discoloration, for example, it first becomes necessary to decide whether the discoloration occurs within the furnace or outside the furnace. Then the type of discoloration must be determined—that is, whether it is a film of oxide, sulfide, zinc, or carbon. When the type of discoloration is known, there are certain common sources which can be investigated, as indicated in the tabulation. Once these causes are found, they can be corrected in a manner which is usually obvious; but Table XXI includes numerous suggestions for handling specific situations.

An important portion of Table XXI is the list (at the righthand side of the table) of references to previous parts of this serial in which discussions, suggestions, and descriptions of tests relating to the various points can be found. These references provide the basis for fairly complete understanding of the conditions involved.

This article is so paged that, without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—EDITOR



This central gas-producing plant provides 8000 cfh of CO_2-free dry combusted gas (Neutralene) for a variety of heat-treating operations



Gas-producers for providing protective atmospheres to the box-type furnace at the right. From left to right: ammonia dissociator, activated-alumina dryer, and atmosphere gas converter

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*The following will facilitate the location of material published in this serial:

Part	*Issue*	*Figs.*	*Equations*	*Tables*	*Footnotes*
Part I	Nov. 1948, p. 29	1 to 6	None	I and II	None
Part II	Dec. 1948, p. 41	7 to 14	(1) to (18)	III and IV	(1) to (9)
Part III	Feb. 1949, p. 37	15 to 23	None	V and VI	None
Part IV	Mar. 1949, p. 25	24 to 35	None	VII	None
Part V	Apr. 1949, p. 25	36 to 41	None	VIII to X	(10) and (11)
Part VI	May 1949, p. 30	42 to 54	None	XI and XII	(12)
Part VII	June 1949, p. 33	55 to 70	None	XIII to XV	(13) to (17)
Part VIII	July 1949, p. 32	71 to 89	None	XVI	(18) to (23)
Part IX	Aug. 1949, p. 26	90 to 97	None	None	None
Part X	Sept. 1949, p. 38	98 to 108	None	XVII to XIX	(24) and (25)
Part XI	Nov. 1949, p. 30	109 to 116	None	None	(26) to (29)
Part XII	Dec. 1949, p. 46	117 to 131	None	None	(30) to (33)
Part XIII	Feb. 1950, p. 43	132 to 149	None	None	(34) to (42)
Part XIV	Mar. 1950, p. 36	150 to 154	None	None	(43) and (44)
Part XV	Apr. 1950, p. 36	155 and 156	None	XX	None
Part XVI	May 1950, p. 26	None	None	XXI	None

TABLE XXI

A SUMMARY OF WHAT TO LOOK FOR AND WHAT TO TRY IF THINGS GO WRONG

	Part No.	Page No.	Column No.	Fig. No.	Table No.	Test No.
(1) *When nonferrous metals discolor within the furnace and it is desired to have them emerge as bright as possible:*						
Determine type of discoloration						
Oxide	XV	37	1	—	—	I
Sulfide	XV	37	1, 2	—	—	I, IV
Zinc distillation	XV	38	1	—	—	—
Carbon	II	42	1	—	—	—
A. If oxide, look for:	XV	37	2	—	—	—
	II	42	1, 2	—	—	—
I. Air leaks. Investigate, and repair if necessary:						
(a) Pipe connections						
(b) Stuffing boxes						
(c) Gaskets	XV	39, 40	2, 1	—	—	XII–XV
(d) Pitch seals or sand seals	II	41	1, 2	—	—	—
(e) Doors, for warpage						
(f) Retorts	XV	39	1, 2	—	—	VII–X
(g) Sufficiency of atmosphere gas supply	XV	40	1	—	—	XVI
II. Drafts of air in room	XV	40	1	—	—	XVI
(a) Eliminate at their source; close doors and windows						
(b) Increase or adjust flow of gas to the heating and cooling chambers, if possible, to counteract drafts						
(c) Install screens at ends of furnace to block drafts						
(d) Remodel hoods over doors if necessary						
(e) Adjust dampers in flues from door hoods						
(f) Check adjustment and effectiveness of gas curtains	XI	37	1, 2	—	—	—
(g) Install charging and discharging vestibules on furnace, with gas-tight inner and outer doors						
B. If sulfide, investigate:						
I. Purity of gas:	XV	37	2	—	—	II
(a) Entering gas producer						
(b) Entering furnace (should be sulfur-free)	IV	25–30	2	—	—	—
(c) Within furnace (should be sulfur-free)						
II. Brick, mortar, and insulation:	XV	37	2	—	—	III
(a) By heating sample in hydrogen atmosphere						
III. Lubricants on work (should be sulfur-free):	XV	37	2	—	—	III
(a) By vendor's data						
(b) By qualitative analysis						
(c) By heating sample in hydrogen atmosphere						
C. If zinc distillation, investigate:	XV	38	1	—	—	—
I. Temperature						
(a) Use minimum						
II. Time at temperature						
(a) Use minimum						
III. Moisture and CO_2 content of gas						
(a) Use minimum						
IV. Zinc vapor pressure						
(a) Sinter brass parts under metal covers if necessary						
V. Hydrogen content of atmosphere						
(a) Use maximum						
D. If carbon, investigate:						
I. Lubricants on work entering furnace	II	42	1	—	—	—
(a) Should be completely volatile type						
(b) Should be removed if unable to use volatile-type						
(2) *When nonferrous metals emerge from cooling chamber bright, but discolor upon striking the air:*						
Determine type of discoloration						
Oxide from being too hot	XV	37	1, 2	—	—	I
Sulfide from sulfur in room air	XV	37	1, 2	—	—	I, IV
A. If oxide, check temperature of outgoing work, and if too high, try to:	II	42	1, 2	—	—	—
I. Increase flow of water through furnace cooling chamber						
II. Slow down rate of travel of work to allow more cooling time						

TABLE XXI (Cont'd)

A SUMMARY OF WHAT TO LOOK FOR AND WHAT TO TRY IF THINGS GO WRONG

	Part No.	Page No.	Column No.	Fig. No.	Table No.	Test No.
III. Diminish heat developed by flame curtain if used at the discharge opening	XI	37	1, 2			
(a) Reduce fuel-gas flow to curtain						
(b) Move work faster through curtain						
(c) Shut off gas flow to curtain and pilot to eliminate flame, also reduce door opening to a minimum						
(d) If protective atmosphere gas is inflammable, shut off gas flow to the curtain, leaving pilot burning. Raise discharge door and allow idle flame of atmosphere gas to burn back into throat						
(e) Replace flame curtain with asbestos or fibre-glass curtains						
IV. Check furnace cooling chamber for presence of lime, scale, or mud in the water jacket. Clean out if necessary						
B. If sulfide, check room air for sulfur contamination	XV	37	2	-	—	IV
(3) *When ferrous metals discolor within the furnace:*	II	42	1, 2	—	—	—
Determine type of discoloration						
Oxide	XV	38	1, 2	155	—	V, VI
Carbon	XV	38, 39	2, 1	—	-	—
A. If oxide, look for:	II	42	1, 2	—	—	—
	IV	28	1	29	—	-
I. Air leaks. Investigate, and repair if necessary:						
(a) Pipe connections						
(b) Stuffing boxes						
(c) Gaskets	XV	39, 40	2, 1			XII–XV
(d) Pitch seals or sand seals	II	41	1, 2			—
(e) Doors, for warpage						
(f) Retorts	XV	39	1	—		VII–X
(g) Sufficiency of atmosphere gas supply	XV	40	1	—	-	XVI
II. Drafts of air in room	XV	40	1	-	-	XVI
(a) Eliminate at their source, close doors and windows						
(b) Increase or adjust flow of gas to the heating and cooling chambers, if possible, to counteract drafts						
(c) Install screens at ends of furnace to block drafts						
(d) Remodel hoods over doors if necessary						
(e) Adjust dampers in flues from door hoods						
(f) Check adjustment and effectiveness of gas curtains	XI	37	1, 2	—	—	-
(g) Install charging and discharging vestibules on furnace, with gas-tight inner and outer doors						
III. Water in furnace cooling chamber:						
(a) Condensation	XV	40	1	—	—	XVII
(1) Try reducing flow of cooling water						
(2) Try reducing moisture content of atmosphere gas. See 3A, IV, (a)						
(b) Leaks	XV	40	2	—	–	XVIII
(1) Welded joints						
(2) Rusted-through spots						
(3) Porosity in cast housings for water-cooled bearings for rolls and fans						
IV. Moisture in gas atmosphere. Check:	XV	38	1, 2	155	—	V, VI
	II	43, 44	1, 2	10	III	—
	IV	28–30	1, 2	30–33	VII	—
	VIII	35, 39	1, 2	74, 89	-	-
(a) Performance of surface cooler of atmosphere-gas producer						
(1) Check temperature of cooling water						
(2) Clean condensing tubes if needed						
(3) Try increasing flow of cooling water						
(4) Look for water leaks in tubes or header						
(5) Look for condensate in gas lines from atmosphere producer to furnace						
(6) Check for proper operation of condensate trap						
V. Improper input air-gas ratio to atmosphere-gas converter	II	42–44	1, 2	10	III	—
(a) Try lower ratio	IV	27	2	28	—	—
VI. Air carried in with work	XV	38	1, 2	155	—	V, VI
	II	41, 44	1, 2	—	III	—
(a) Purge large chambers and long coiled tubes						

TABLE XXI (Cont'd)

A SUMMARY OF WHAT TO LOOK FOR AND WHAT TO TRY IF THINGS GO WRONG

	Part No.	Page No.	Column No.	Fig. No.	Table No.	Test No.
VII. Air or water in quenching oil	XV	38, 39	1, 2	155	XX	V, VI
B. If carbon, investigate:	II	42	1	—	—	—
I. Lubricants on work entering furnace						
(a) Should be completely volatile type						
(b) Should be removed if unable to use volatile-type						
(4) *When ferrous metals emerge from cooling chamber bright but discolor upon striking the air, because of oxidation:*	II	42	1, 2	—	—	—
A. Check temperature of outgoing work and, if too high, try to:						
I. Increase flow of water through furnace cooling chamber						
II. Slow down rate of travel of work to allow more cooling time						
III. Diminish heat developed by flame curtain, if used at the discharge opening						
(a) Reduce fuel-gas flow to curtain						
(b) Move work faster through curtain						
(c) Shut off fuel-gas flow to curtain and pilot to eliminate flame, also reduce door opening to a minimum						
(d) If protective-atmosphere gas is inflammable, shut off gas flow to the curtain, leaving pilot burning. Raise discharge door and allow idle flame of atmosphere gas to burn back into throat						
(e) Replace flame curtain with asbestos or fibre-glass curtains						
IV. Check furnace cooling chamber for presence of lime, scale, or mud in the water jacket. Clean out if necessary						
(5) *When medium- and high-carbon metals decarburize in supposedly nondecarburizing atmospheres:*	II V	44–48 25–28	1, 2 1, 2	11–14 36–41	III VIII–X	— —
A. Look for excessive water vapor in atmosphere gases entering furnace	XV II IV VIII	40 44 28, 29 35, 39	2 1, 2 1, 2 1, 2	— — 29–32 74, 89	— III VII —	— — — —
I. In Neutralene gas	VI	30–35	1, 2	42–51	XI, XII	—
(a) Check temperature of gas leaving absorbing tower (1). See 3A, IV for aid in investigating gas cooler						
(b) Investigate effectiveness of refrigerated-gas cooler Look for:	IV	28, 29	1, 2	30–32	III	—
(1) Loss of refrigerant						
(2) Inadequate cooling-water supply						
(3) Improper functioning of temperature controls						
(c) Study performance of regenerative-type dryer Look for:	IV	30	1, 2	33		—
(1) Inadequate reactivating cycle (sufficient time and temperature for both heating and cooling)						
(2) Reduced absorbing capacity due to accidental overheating or contamination						
II. In Thermalene gas, look for:	VI	36, 37	1, 2	52–54	—	—
(a) Inadequate operating temperature						
(b) Excessive input air-gas ratio						
(c) Reduction of hydrocarbon-content in fuel-gas supply						
(d) Reduced effectiveness of catalyst						
(1) Try removing carbon when incandescent, with air or steam						
B. Look for excessive water vapor in atmosphere gases within furnace due to:	XV II VIII	40, 41 44 35, 39	2, 1 1, 2 1, 2	— — 74, 89	— III —	XX — —

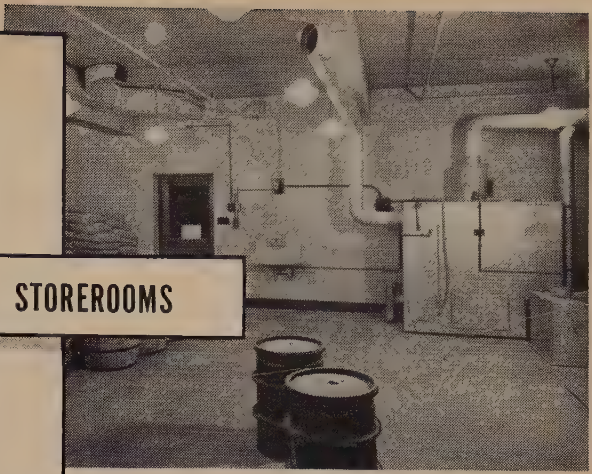
TABLE XXI (Cont'd)

A SUMMARY OF WHAT TO LOOK FOR AND WHAT TO TRY IF THINGS GO WRONG

	Part No.	Page No.	Column No.	Fig. No.	Table No.	Test No.
I. Inadequate purging and drying of brickwork	XI	31–34	1, 2	—	—	—
	XV	40, 41	2, 1	—	—	XX
II. Oxygen carried in with the work	II	41, 44	1, 2	—	III	—
(a) Air						
(b) Moisture						
(c) Oxides on surfaces of parts						
III. Air leaks. Investigate, and repair if necessary:						
(a) Pipe connections (b) Stuffing boxes (c) Gaskets (d) Pitch seals or sand seals (e) Doors, for warpage	XV II	39, 40 41	2, 1 2	— —	— —	XII–XV —
(f) Retorts	XV	39	1	—	—	VII–X
(g) Sufficiency of atmosphere gas supply	XV	40	1	156	—	XVI
IV. Drafts of air in room	XV	40	1	—	—	XVI
	II	41	2	—	—	—
(a) Eliminate at their source; close doors and windows						
(b) Increase or adjust flow of gas to the heating and cooling chambers if possible, to counteract drafts						
(c) Install screens at ends of furnace to block drafts						
(d) Remodel hoods over doors if necessary						
(e) Adjust dampers in flues from door hoods						
(f) Check adjustment and effectiveness of gas curtains	XI	37	2	115	—	—
(g) Install charging and discharging vestibules on furnace, with gas-tight inner and outer doors	XV	40	1	156		XV
V. Water in furnace cooling chamber						
(a) Leaks						
(1) Welded joints	XV	40	2	—	—	XVIII
(2) Rusted-through spots						
(3) Porosity in cast housings for water-cooled bearings for rolls and fans						
C. Look for CO_2 in atmosphere entering furnace	II	44, 46	1, 2	—	III	—
	V	27	1	—	—	—
	VIII	34–38	1, 2	73–80	—	—
I. In Neutralene gas, look for:	VI	30–34	1, 2	42–51	XI, XII	—
(a) Check CO_2 removing solution (monoethanolamine) for:						
(1) Sufficient flow						
(2) Proper cooling						
(3) Sufficient concentration						
(4) Proper reactivation						
(b) Check for leaking bypass valve at absorbing tower						
II. In Thermalene gas, look for:	VI	36, 37	1, 2	52–54	—	—
(a) Inadequate operating temperature						
(b) Excessive input air-gas ratio						
(c) Reduction of hydrocarbon-content in fuel-gas supply						
(d) Reduced effectiveness of catalyst						
(1) Try removing carbon when incandescent, with air or steam						
D. Excessive CO_2 in atmosphere gas within furnace due to:						
I. Air leaks. Investigate, and repair if necessary:						
(a) Pipe connections (b) Stuffing boxes (c) Gaskets (d) Pitch seals or sand seals (e) Doors, for warpage	XV II	39, 40 41	2, 1 2	— —	— —	XII–XV —
(f) Retorts	XV	39	1	—	—	VII–X
(g) Sufficiency of atmosphere gas supply	XV	40	1	156	—	XVI
II. Drafts of air in room	XV	40	1	—	—	XVI
	II	41	2	—	—	—
(a) Eliminate at their source; close doors and windows						
(b) Increase or adjust flow of gas to the heating and cooling chambers, if possible, so as to counteract drafts						
(c) Install screens at ends of furnace to block drafts						
(d) Remodel hoods over doors if necessary						
(e) Adjust dampers in flues from door hoods						
(f) Check adjustment and effectiveness of gas curtains	XI	37	2	115	—	—
	XV	40	1	156	—	XV

(Concluded)

Why let WETth in when you . . . have to take it out



in STOREROOMS

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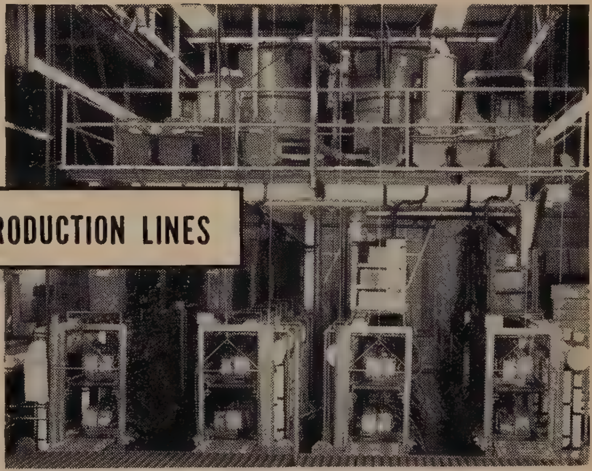

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APPLICATION OF INTERRUPTER SWITCHES TO LOAD-CENTER UNIT SUBSTATIONS . . Part III

Primary Selective Systems and Loop Circuits

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PRIMARY SELECTIVE SWITCHING

The primary selective system differs from the straight radial and the secondary selective systems in that two primary feeders are brought to each substation (Fig. 9). Since two primary feeders are available, a switching means is necessary to select the desired feeder to connect to the substation. The switching function is different also in that there is a transfer function to be performed and not the mere disconnecting of a primary feeder as in the two previously mentioned systems (Figs. 2 and 8, in Part I).

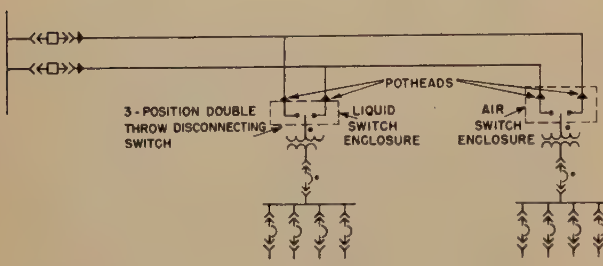

Fig. 9. Primary selective load-center system with double-throw interrupting switches

The safe way to make the transfer is with adequate power circuit breakers as shown in Fig. 10. However, the cost of such an arrangement may not be justified; and in an attempt to reduce cost, interrupter switches are often proposed as a substitute for power circuit breakers. Whether the service reliability feature of having two primary feeders available is or is not realized when interrupter switches are used depends upon the design and arrangement of the transfer switches. Two types of transfer switches are available: one is the double-throw type (Fig. 11); the other consists of two separate single-throw switches, as shown in Fig. 12. Double-throw switches necessitate bringing both feeders into the same compartment whereas two separate switches enable termination of the feeder cables in separate compartments. This accounts for the real difference in service reliability and a major portion of the difference in safety obtained from the two different interrupter switch transfer means. Both arrangements involve a real hazard should a transfer be made with a fault on the load side of the transfer switch with the primary feeder energized. These differences are now to be considered in detail.

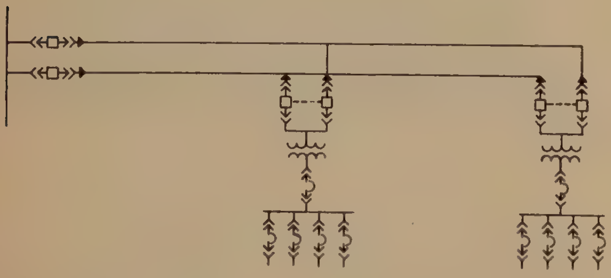

Fig. 10. Primary selective load-center system with power circuit breakers

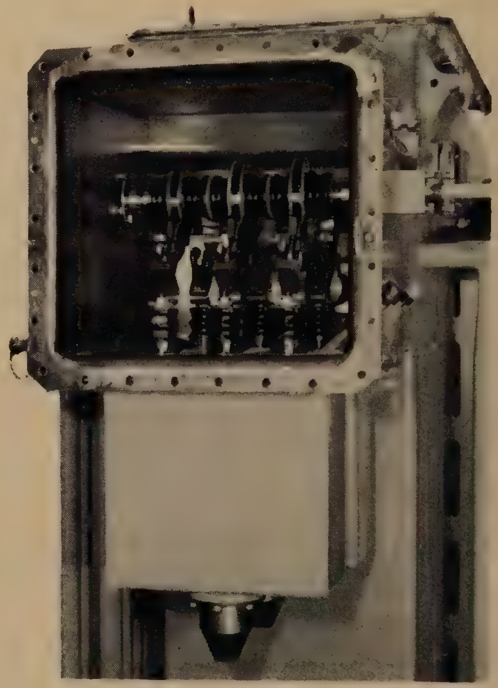

Fig. 11. Discontinued style of double-throw liquid-filled switch for primary selective systems. Note both potheads on bottom of box

Fig. 11 shows that, with both potheads adjacent to each other, a failure in one will more than likely involve both and shut down both feeders. Furthermore, there is

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This article is so paged that, without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—Editor

no possibility of isolating one feeder and its pothead through an air break, so that it can be worked on in safety with the second feeder energized.

In any throw-over scheme with interrupter switches, there is always the hazard of operating under fault conditions. To overcome this hazard the operator should, after a tripout, shut down both feeders, make the transfer, and then reclose the good feeder. Although transformer failures are rare, when a primary feeder trips out the operator does not know whether the fault is in a transformer or the cable. If this failure should happen to be in the transformer and if the operator attempts to restore service by throwing the double-throw primary switch to the opposite position without first de-energizing the good primary feeder, he will connect the faulty transformer to a live feeder through the interrupter switch. Operation of interrupter switches under such conditions may result in fatalities and a complete shutdown of both feeders. Such cases of failure have occurred.

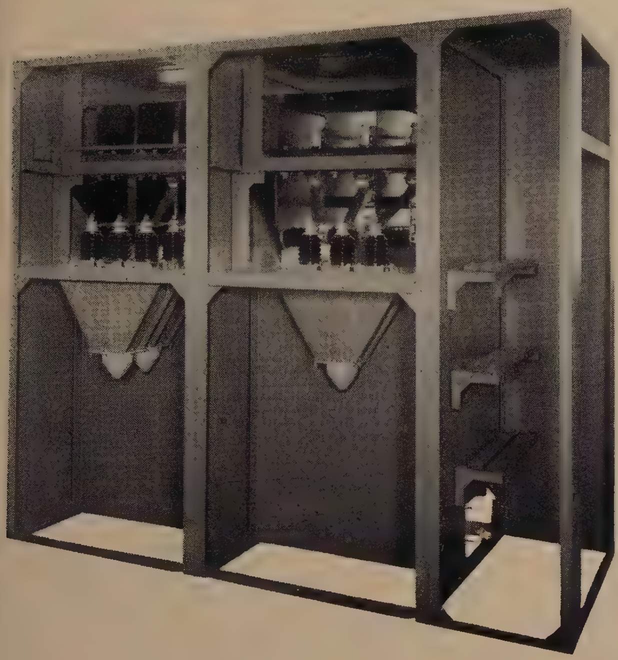


Fig. 12. Modern air-filled switches for primary selective system. There are two single-throw switches in separate metal-enclosed compartments. These in turn are separated from incoming-line potheads. Potheads are in separate metal-enclosed compartments in the cubicles

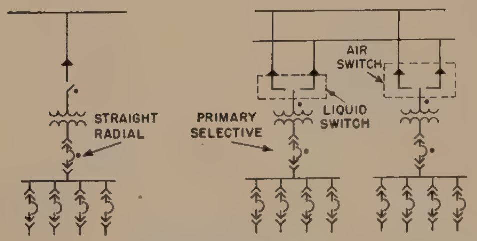
Contrasted with this, the interrupter switch on a radial or secondary selective arrangement is for maintenance purposes only and not for operation of, or for switching of, the system. The hazard of transferring a faulty transformer is not present in these arrangements because there is no second feeder available.

The cost of these two arrangements—that is, the straight radial and the primary selective with double-throw interrupter switches—cannot be compared directly. The cost of a primary selective substation with double-throw switches varies compared with radial substations from slightly more, percentage-wise, for larger substations to substantially more, percentage-wise, for smaller substations (those of approximately 200 kva or less). The real increase in cost of the primary selective system compared with the radial arrangement is in the duplicate primary feeder cable (at a cost of $3 to $10 per foot) required for the primary selective arrangement. The operating and safety characteristics of the primary selective arrangement with double-throw switches and a straight radial arrangement are summarized in FIG. 13.

Based on the foregoing, it is felt that either the radial or the secondary selective arrangement should be used instead of the primary selective arrangement with double-throw interrupter switches. The secondary selective arrangement has better service reliability and the radial arrangement has essentially as good service reliability. *Neither* arrangement has the safety hazard of the primary selective arrangement with a double-throw interrupter switch.

Where, for unusual reasons, a primary selective arrangement with interrupter switches for transferring from one cable to another must be provided, it is felt that the design of the interrupter switches should be such as to enable restoring of service after a primary feeder failure and yet permit safe replacement of the faulty section of primary cable and to permit safe inspection of potheads, which are generally the weakest point in a cable system; in other words, the switch design should permit the realization of the service reliability of the primary selective arrangement apparent in the one-line diagram and paid for by the owner. For these applications, two interlocked single-throw switches should be used. A view of such a switch with the steel back plates removed is shown in FIG. 12. Note that metal barriers are placed around each set of potheads, which permits, with proper precautions, the servicing of either feeder pothead with the other feeder energized.

To be the more certain of getting this higher-quality equipment, the one-line diagram of the circuit should



COMPARISON

	RADIAL	PRI SEL
1. COST		
a. SUBSTATIONS	100%	105 - 150%
b. PRIMARY CABLE	100%	100 - 200%
2. SERVICE RELIABILITY		
a. CABLE FAILURE	OUT	OUT (TO MAKE REPAIRS)
b. TRANSFORMER OUT	SAME	
c. POTHEAD FAILURE	OUT	OUT (IN MOST CASES)
d. SWITCH FAILURE	SAME	
e. MAINTENANCE OF SWITCH	SAME	
3. SERVICE	GOOD	VERY LOW
4. SPACE		MORE
5. LOSSES AND VOLTAGE DROP	SAME	
6. COMPLEXITY		SLIGHTLY MORE COMPLICATED

Fig. 13. Comparison of radial unit substation with primary selective load-center systems

always be drawn as shown in Fig. 14 to clearly indicate two single-throw switches. However, two single-throw switches still involve the hazard of transferring a faulty transformer to an energized feeder by means of the interrupter switch. Although the probability of this may be remote, in the interest of safety the transfer from one feeder to another with any kind of interrupter switch should always be made with both feeders de-energized. As pointed out previously, a high degree of safety in the primary selective arrangement can be realized only by using incoming line power circuit breakers. Therefore, the reduction in cost by using interrupter switches instead of power circuit breakers may very likely be at an undue sacrifice in safety.

However, if after a review of all facts it is felt that a primary selective system with interrupter switches is required, then an arrangement as shown in Figs. 12 and 14 with two interlocked single-throw switches should always be used in preference to the arrangement shown in Figs. 9 and 11 with double-throw switches, for the reason outlined previously and summarized in Fig. 13.

PRIMARY SELECTIVE SECONDARY NETWORK SYSTEMS

Sometimes it is proposed to use a primary selective *network system* (Fig. 15) to reduce the inherently high cost of the conventional network system. The former are generally considered to have double-throw disconnecting switches for the transfer means. One of the major reasons for putting in a secondary network is to obtain a high order of service reliability. The application of the primary selective feature is intended as a means of reducing the required transformer capacity and therefore the cost. When one feeder goes out, the remaining transformers may be badly overloaded; but it is supposed that the transfer can be made quickly by the primary selective interrupter switches to re-establish service through all the transformers.

As has been pointed out previously, in the interest of safety, the transfer should not be made until both circuits have been de-energized. This may result in a complete shutdown even with a network system. If both circuits are not de-energized there is the hazard of closing in an energized feeder on a faulty transformer with an interrupter switch. This shuts down both feeders and drops service, to say nothing of the hazard to the operator if the switch should fail. These conditions apply, of course, whether two single-throw or one double-throw switch is used. With the double-throw switch, all the poor service reliability features already pointed out are present to detract from the network system. Hence, it does not seem wise to spend extra money for the network system and then introduce a hazardous bottleneck such as the use of double-throw interrupter switches in the load center substations. Rather, if the reliability expected from the added investment in a network system is to be realized, the simple, relatively safe, single-throw interrupter switches should be used.

LOOPED PRIMARY FEEDER SYSTEMS

The systems so far considered all had radial primary feeders. In some cases, looped primary feeders are proposed such as that illustrated in Fig. 16. Sectionalization of the loop requires switching means at the points indicated numerically. The only really safe way to sectionalize an energized looped primary is with properly applied power circuit breakers at these points, as shown in Fig. 17. As in the primary selective system, the cost of power circuit breakers for the switching function where small substations are used may be prohibitive and hence there is often the tendency to cheapen the looped primary system by using interrupter switches, as shown in Fig. 16, instead of power circuit breakers.

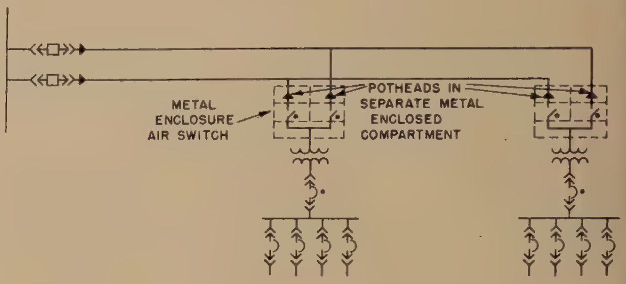


Fig. 14. Primary selective load-center system with two single-throw switches

When this is done, practically all the advantages of the loop that seem apparent in the one-line diagram are lost, so far as service reliability is concerned, and safety is brought to a very low order for the following reasons:

(1). A fault anywhere drops all load until the fault is found and isolated. This may require several hours

(2). There is no practical way of interlocking the interrupter switches to assure that they will not be operated under short-circuit conditions

(3). If certain types of *separately mounted* oil-filled switches are used, there is no visual means of being sure the circuits are cleared when it is desired to work on one piece of cable with the rest of the system energized. Oil generally darkens and makes sight glasses useless.

Most operators will not permit working on a cable isolated only by contacts under oil because of the possibility of leakage through old carbonized or wet oil.

The most serious disadvantage of this system is the hazard of operating the interrupter switches under high overload or fault conditions. While it is easy to consider academically what an operator will do when a fault occurs, the result is too apt to work out differently in actual practice. In the first place, faults do not occur every day; so, no matter how good the operating instructions, there is little if any occasion to practice operating the system properly. Hence, in the rush to restore service after a fault has occurred, the operator can too easily make many possible mistakes. First of all, when a one-line diagram is visible, the entire system is before one's eyes and it is easy to see what to do. But when the operator leaves the powerhouse to operate a switch, he has only a mental picture of the system and must rely entirely on memory. Because it is easy to become confused when under pressure he may go to the wrong switch, or he may close instead of open the switch, or he may move it to the wrong position.

For example, let us follow through the case of isolating a cable fault, say at X in FIG. 16, assuming of course that the operator does not know where the fault is but simply that both breakers tripped out. This is no help in locating the fault. It merely indicates the occurrence of a fault somewhere. The first operation may be to open Switches 1 and 6 and reclose both breakers. Since the breakers stay in, the fault has not been found. So, the operator will start through the system throwing switches and closing breakers, hoping that the sequence is correct; for, if it is not, the results may be a switch blow-up and a severely injured man. If the operator is lucky and starts at the left side, the fault will be isolated at the third try because second operation of closing Switch 1 and opening Switch 2 will show the fault is not in the transformer. The third operation is to close 2 and open 4. This will show where the fault is. A little study of FIG. 16 reveals how many more times this process would have to be repeated before the fault is located, if the switching operations had started at the right.

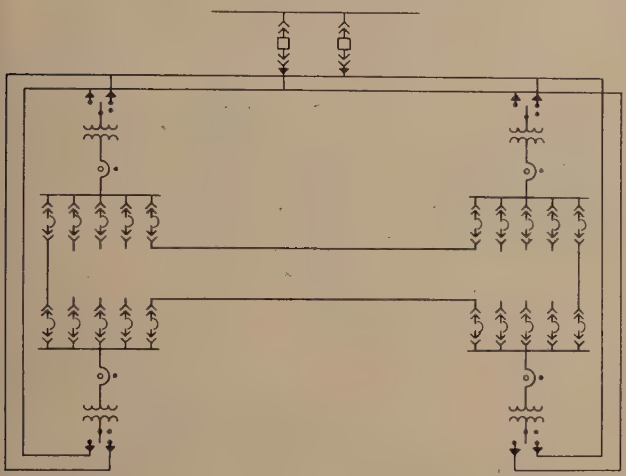


Fig. 15. Primary selective network system

It is essential that the power circuit breakers at the source be opened every time a switch is thrown. If the circuit breaker were not opened, because of an error or misunderstood directions, and the No. 2 switch in this example was closed, then it would be closed on a fault. The operation is so complicated that the probability of making a mistake is very high and is faced over and over again.

The suggested alternative to any kind of a loop system is always either a straight radial system or a secondary selective system. In some layouts where there are scattered small buildings (such as nurses' or attendants' quarters at a hospital) the straight radial system should serve well enough, because service continuity in these is no more essential than in an ordinary dwelling, most of which are fed by radial systems. However, some engineers may feel that, since the feeders to these isolated buildings are underground, some primary duplication is necessary.

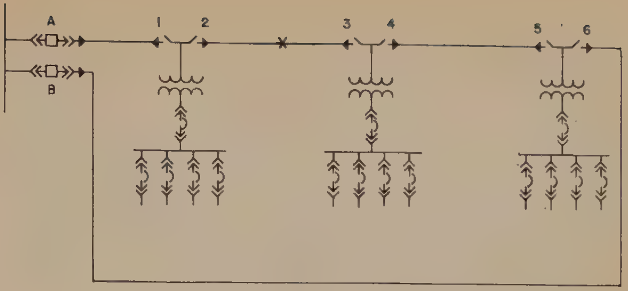


Fig. 16. Loop-circuit system with sectionalizing switches

If so, and the secondary selective system does not fit, then the primary selective system (FIG. 14) may be employed, in place of the loop feeders with interrupter switches for sectionalization. The primary selective system, when using interrupter switches, has one hazard as pointed out earlier; but that hazard is far less than the hazard of the loop system with interrupter switches. When an outage occurs in the primary selective system, the operator knows on which feeder it is; and only one-half the load is dropped. It is necessary to drop both feeders to make the transfer safely. If the fault is not in a transformer, all service is restored after one operation—which is much quicker than is probable by the loop system with switches. There is only one sequence for the primary selective system, hence the chances are less for making a serious operating error with the interrupter switches. However, when specifying the primary selective system for these applications it is most important, as pointed out previously, to specify two interlocked single-throw switches instead of one double-throw switch. This type of primary selective system compares favorably in first cost with loop systems when the same types of switches are used in both systems.

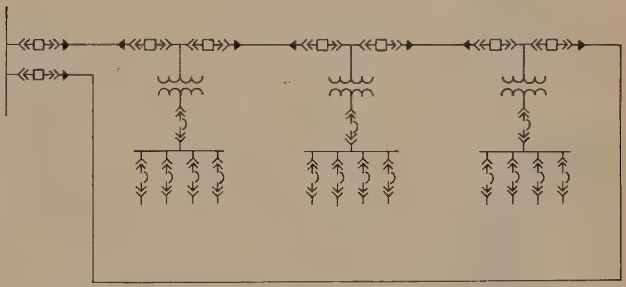


Fig. 17. Loop-circuit system with power circuit breakers

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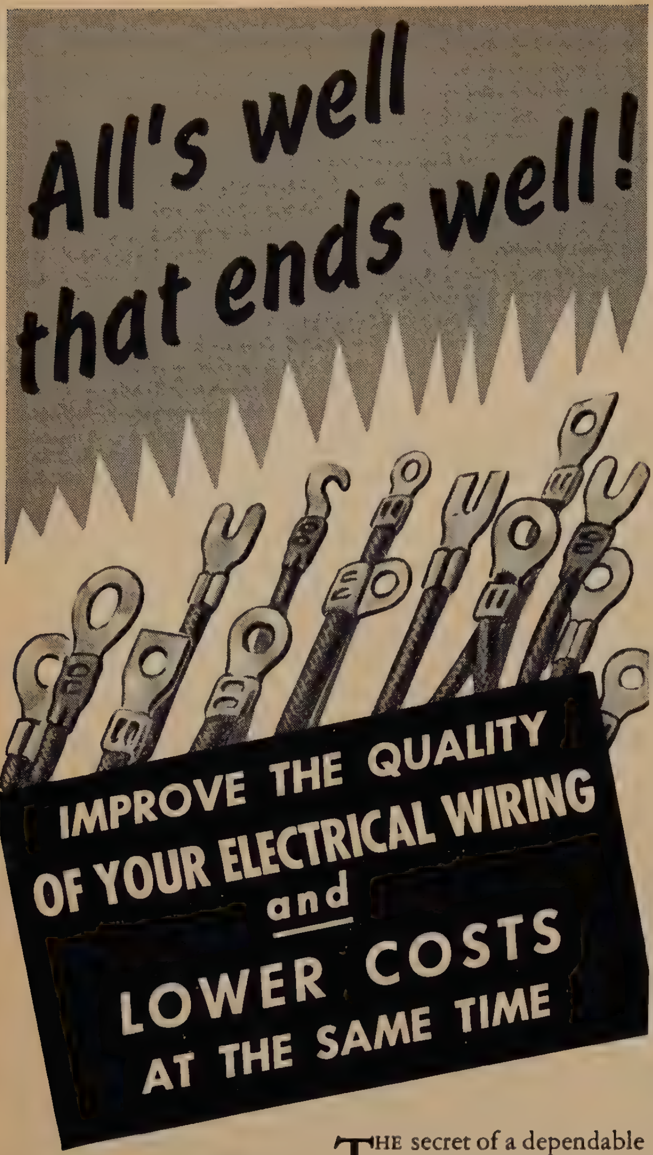
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APPLICATION OF INTERRUPTER SWITCHES

(Continued from preceding page)

SUMMARY

The foregoing principles and suggestions are based on the cumulative experience and observations of the authors. The comments and suggestions are offered to assist industrial plant engineers to continue designing the most economical systems possible and yet maintain a level of personnel safety and service continuity that is consistent with good industrial practice.

The following points summarize this discussion:

(1). The interrupter switch, properly applied to unit substations, contributes materially to a lower-cost power distribution system

(2). The interrupter switch should always be interlocked for maximum safety to personnel and equipment

(3). Radial or secondary selective systems should always be used in preference to primary selective or loop systems if at all possible

(4). If primary selective systems must be used with interrupter switches, it should be made certain that two separate interlocked single-throw switches are specified rather than *one*, double-throw switch

(5). Loop primary feeder systems are almost always least desirable for load-center power systems in industrial plants.

(*Concluded*)

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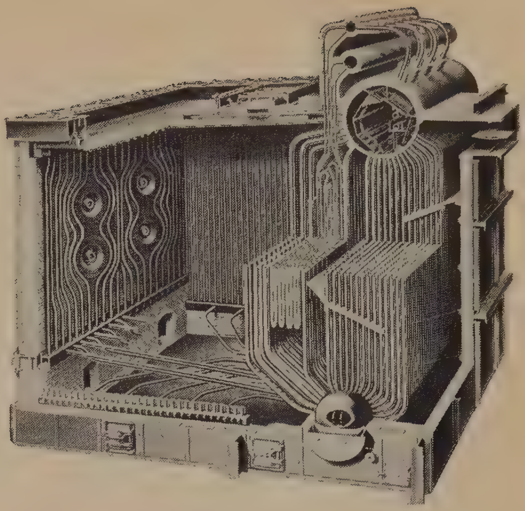

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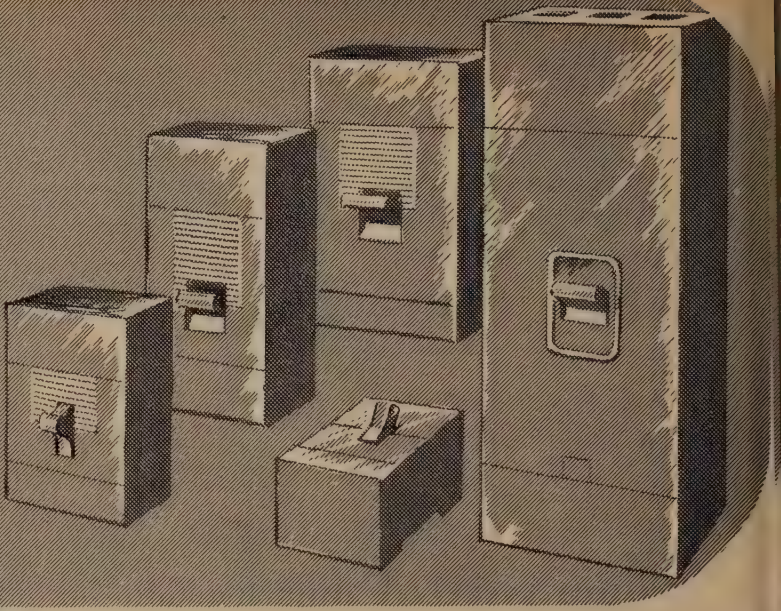

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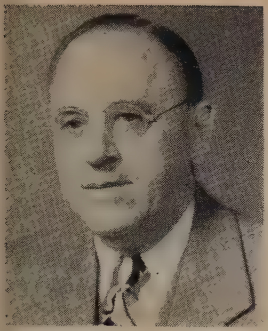
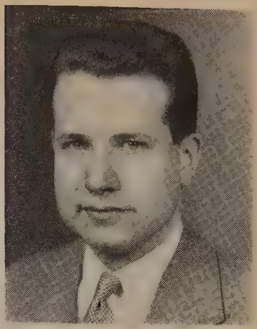


T. C. Aitchison

HERMETICALLY SEALED CAST-GLASS BUSHINGS



H Brunton Jr.

The advantages of reliability, permanence, and ease of attaching are combined in a modern technique of producing electrical apparatus

By T. C. AITCHISON and H. BRUNTON
Bushing Engineering Division Transformers & Allied Products Sales Div.
General Electric Company, Pittsfield, Mass.

FOR many years, complete hermetic sealing has been a goal in the design of several types of electrical apparatus. The introduction of cast-glass bushings made this goal practical, and for the last ten years, a few types of apparatus have been equipped with them. While cast-glass bushings have been developed for some time, until recently their use has been restricted because of limited production facilities. That problem has been solved and it is now possible to supply cast-glass bushings in quantity. Thus, at this time, it seems particularly appropriate to review the development of this new product and to explore applications which can now be made.

DEVELOPMENT

The need for reliable, hermetic sealing has been recognized since the introduction of liquid- and gas-filled electrical apparatus. Complete sealing is required to prevent moisture and other contaminants from entering apparatus and also to assure that any enclosed liquid or gas does not leak out.

With this objective in mind, tank and container designs were improved to limit the number of joints, and seam welding was introduced. By application of these practices, complete sealing was obtained except at the point where bushings were attached to the apparatus. New and improved gasket materials, such as nitrile and silicone, have provided very effective seals at these bushing entrances; but for several types of electrical apparatus a direct seal between the container and bushing is desired.

The first approach to the problem was to solder the metal terminal cap and mounting flanges of the bushing to metalized surfaces fired on to the conventional porcelain insulator. These solder-seal bushings, using old materials adapted to new uses, have been very satisfactory as single-conductor bushings. Multi-conductor bushings of this kind would be uneconomical, however, because of the many required soldering operations and the poor space factor that would result.

A more direct approach appeared to be that of embedding metal parts and sealing them in the ceramic insulator. Porcelain could obviously not be used for the insulator because of its high shrinkage after forming, but glass offered a feasible solution to the problem. It is essential, however, that the thermal expansion of the glass and metal(1) be properly co-ordinated to prevent excessive strain in the glass. Numerous compositions of glasses and metals were used to determine the combination which would give maximum thermal shock resistance, good weathering characteristics, and the most reliable sealing qualities.

By 1939 this development had progressed(2) to the point where satisfactory bushings could be cast. Molten glass was poured around metal parts located in molds, leaving the sealing portion of the metal parts embedded in glass. Several hundred of these bushings, solder-attached to power-factor-improvement capacitors, were placed in service on distribution lines. After ten years of service these bushings are still operating satisfactorily.

With the advent of the war, an urgent need developed for reliable hermetically sealed electrical apparatus to operate under unusually severe conditions of high humidity, in climates where organic materials were subject to attack from fungus growths. This need led to a greatly increased demand for bushings to be solder-attached to all-welded apparatus cases, to eliminate any exposure of organic materials to the air. In many cases, the compact structure of the bushings also made it possible to reduce the over-all size and weight of electrical apparatus where reduced weight was at a premium, as in air-borne equipment. Many thousands of these bushings were used during the war to excellent advantage and since then their use has continued to expand.

APPLICATION

At the present time, more than 400,000 glass bushings of numerous designs and ratings are in successful operation on various types of electrical apparatus where reliable hermetic sealing is essential. The bushings are either single- or multiple-conductor and can be produced in solid-conductor or draw-lead types (FIG. 1). Other bushings are particularly suited for electronic

This article is so paged that, without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—EDITOR

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(1) "The Expansion Characteristics of Some Common Glasses and Metals," by E. E. Burger, GENERAL ELECTRIC REVIEW, vol. 37, February 1934, p. 93.

(2) "Sealed Glass Bushings for Electrical Apparatus," by Dr. A. W. Hull, Dr. R. W. Moore, and O. H. Doll, GENERAL ELECTRIC REVIEW, vol. 42, December 1939, p. 525.

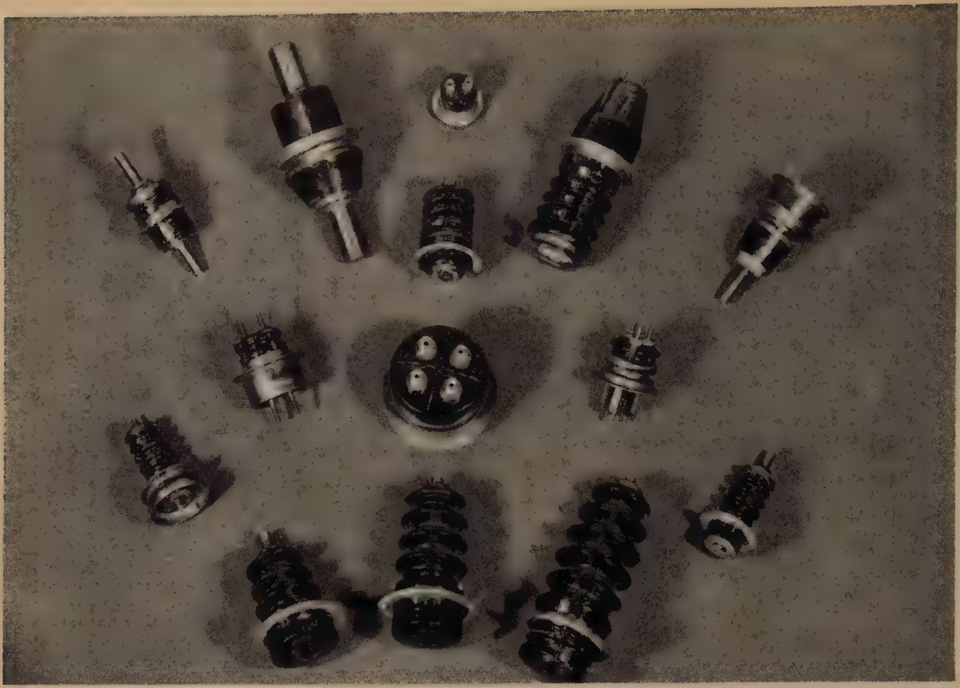


Fig. 1
Various types of single- and multiple-conductor cast-glass bushings

applications, as they are provided with a top flange to permit mounting tube sockets directly on the bushing.

Bushings are now made in large quantities for voltage ratings up to 15 kv (60-cycle dry 1-minute withstand 50 kv; 60-cycle wet 10-second withstand 45 kv; positive or negative impulse withstand 110 kv) and for current ratings up to 1200 amp. For certain types and ratings, standard designs have been developed, but special designs can be produced if sufficient demand for them arises.

While glass bushings were originally used in vital communication equipment where severe operating conditions were continually encountered, the bushings are now used on many other types of electrical equipment. Perhaps the largest application so far has been made on power capacitors where their use has been justified by excellent performance. Equipped with integral tube sockets, glass bushings are used very effectively on such electronic components as rectifier and filament transformers (Figs. 2 and 3). The compact design of the bushings and their hermetic seal are also taken advantage of in many types of pulse transformers (Fig. 4). Besides these applications, glass bushings have been used also on resonant charging reactors, instrument transformers, and even some types of network transformers. The success that glass bushings have attained to date will undoubtedly, lead to a still greater variety of applications, including higher voltage ratings.

METHODS OF ATTACHING BUSHINGS

Bushings can be conveniently soldered, brazed, or welded (Fig. 5) to apparatus covers, providing that the cover is correctly designed and that the proper method of attachment is used.

Soldering is probably the most widely used method of attaching glass bushings to apparatus covers. The portion of the cover to which the bushing flange is to be attached should normally be of thin cross-section, about twice the thickness of the flange. When severe vibration is expected in service, or when tall bushings are being used, it is desirable first to reinforce the joint by

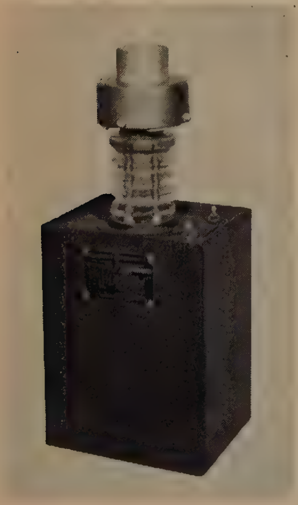


Fig. 2
Cast-glass bushing attached to a filament transformer

Fig. 3
Kenotron rectifier equipped with hermetically sealed cast-glass bushings

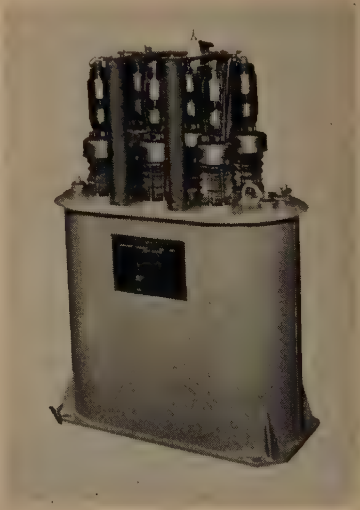
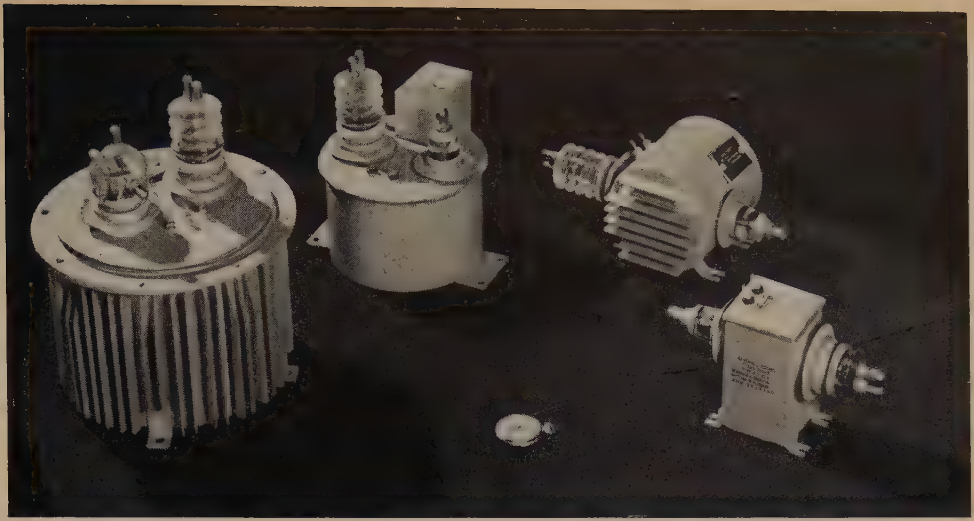


Fig. 4
Hermetically sealed cast-glass bushings on oil-insulated pulse transformers



spot-welding the bushing flange to the cover in several places. The joint is then sealed tightly by soldering.

When glass bushings are to be attached to heavy covers, an intermediate adapter is brazed to the bushing flange at the factory. This adapter is required to minimize the heat in the bushing flange while the bushing is being brazed to the heavy covers.

Welding is used to attach glass bushings to heavy covers, in a manner similar to the applications that are suitable for brazing. Here again an intermediate adapter is attached to the bushing flange at the factory and this adapter is then attached to the apparatus covers by arc- or gas-welding.

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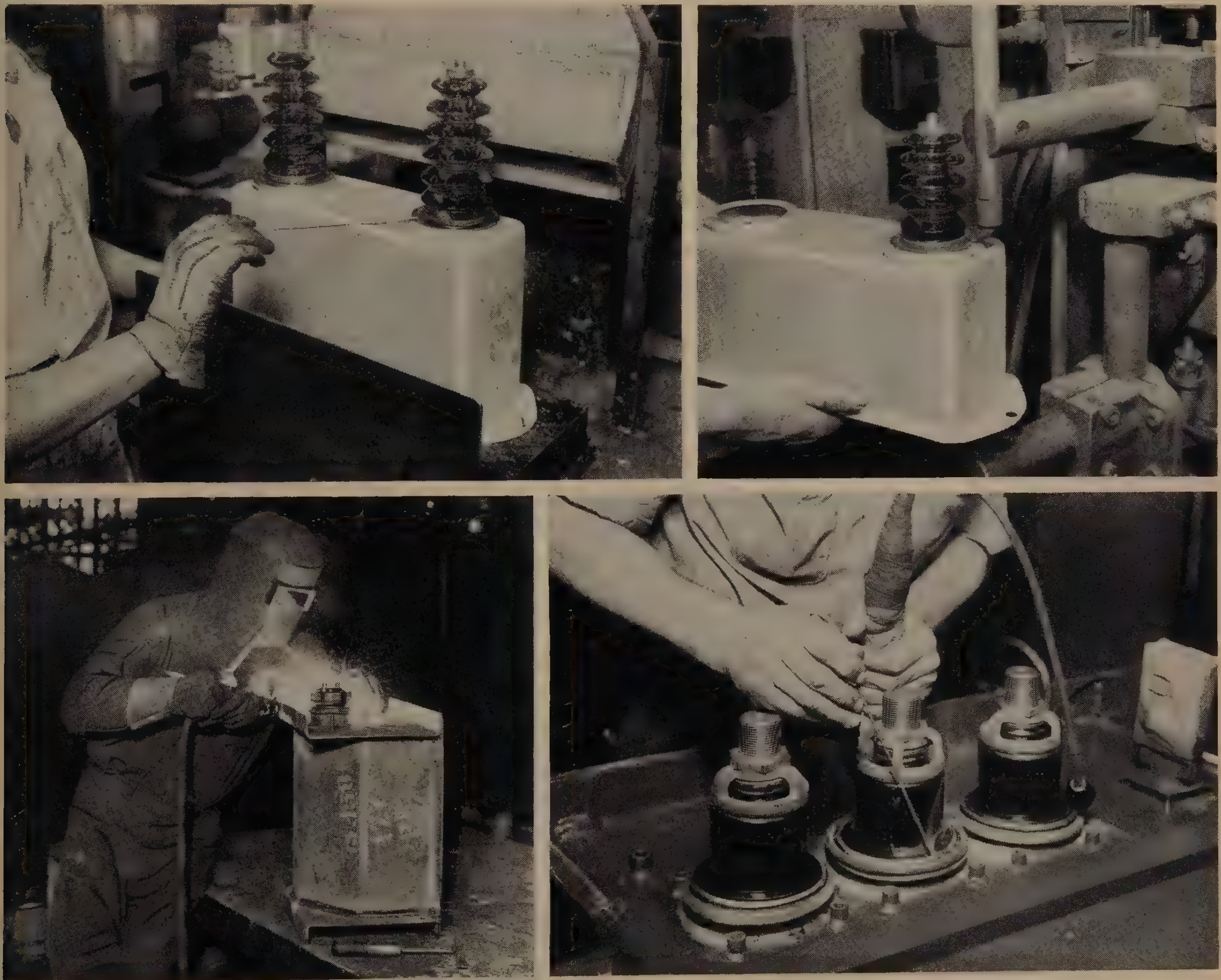


Fig. 5. Typical methods of attaching cast-glass bushings to electric equipment: (*upper left*) two bushings are simultaneously soldered to capacitor case by induction heating (induction coils placed under case), the bushing flanges having been first (*upper right*) spot-welded to the case; (*lower left*) arc welding is used to attach bushings to heavy transformer tanks while (*lower right*) large glass bushings are soldered to a network transformer tank by resistance-heating unit

Glass Bushings

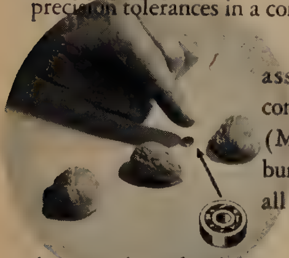
**NOW AVAILABLE
TO MANUFACTURERS
OF ELECTRONIC
EQUIPMENT**

General Electric is now offering to other manufacturers the cast glass bushings it has used so successfully on many types of electrical equipment.

These bushings are cast of stable, low-expansion glass. They are attached directly to the apparatus without gaskets—by soldering, welding or brazing, thus forming a strong, permanent, vacuum-tight seal that eliminates moisture problems and often permits more compact, light-weight design.

Available to meet dry, 60-cycle flashover values of from 10 to 50 kv, and in current ratings of 25 and 50 amperes (in large sizes to 800 amperes), for single or multi-conductor. If you will send us a sketch and ratings of bushings you are now using, we will furnish you with samples of our standard glass bushings. See them and evaluate their advantages. Or write for our Bulletin GEA-5093, *Apparatus Department, General Electric Company, Schenectady, N. Y.*

GENERAL ELECTRIC
411-54



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HERMETICALLY SEALED CAST-GLASS BUSHINGS

(Continued from preceding page)

After ten years of operating experience, hermetically sealed glass bushings have an enviable record. To users, they offer several new design opportunities:

(1). These bushings are easily attached directly to the apparatus, eliminating gaskets and providing a permanent hermetic seal

(2). The small, compact structure of the bushings often makes it possible to reduce the over-all size and weight of electrical apparatus

(3). The bushings have great mechanical strength and are well adapted for use in aircraft or other applications where they are subject to continual vibration

(4). The inorganic nature of the seal makes the bushings particularly suitable for installations subject to high humidity or for climates that foster fungus growths

(5). The bushings are made from exceptionally stable, weather-resistant glass and all the associated metal hardware is special, corrosion-resistant, nickel-steel

(6). When excess potentials, either 60-cycle or impulse, are applied, the bushings will flash over repeatedly rather than puncture or shatter.

Now, with new production facilities that permit the bushings to be made in large quantities, these advantages are available to more and more users. Hermetic sealing—the goal for many years—is at last a reality.

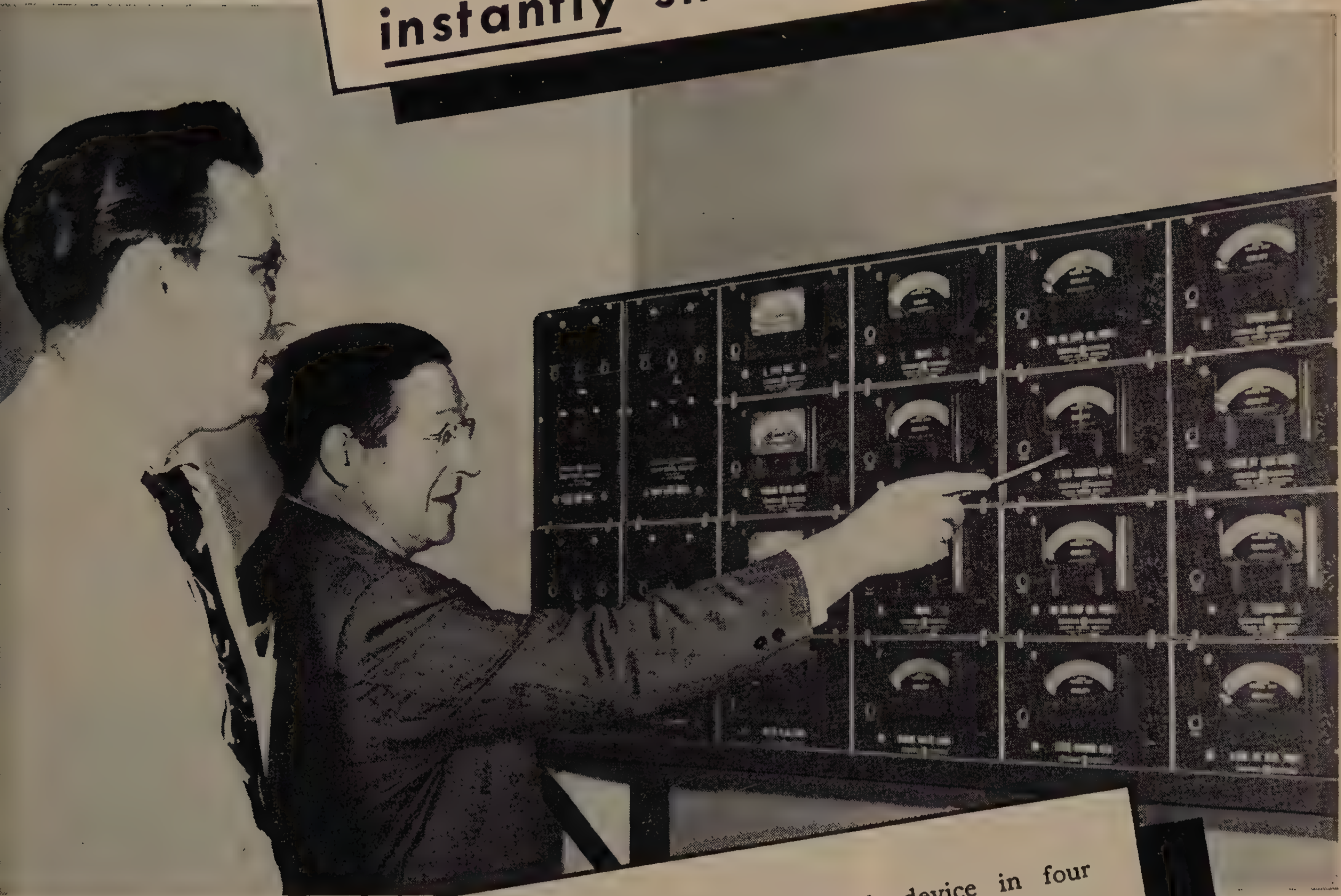
★ For three or more controls operated as a unit in tandem, Clarostat Series 42 is the logical choice. Bakelite cases nest and lock together. Metal end-plates and tie-rods. Rigid assembly. Single shaft passes through and locks with rotor of each control. Up to 20 units. Each unit wound to desired resistance, taper, tap, hop-off. Back lash eliminated.

Write for Engineering Bulletin 142. Let us collaborate on your control problems.

CLAROSTAT
Controls and Resistors
CLAROSTAT MFG. CO., INC. DOVER, N. H.

NEW quality-control indicator

instantly shows reject level



This revolutionary device puts the finger on trouble as soon as it occurs, enabling you to slash rejects and rework.

Developed for G-E, it cut refrigerator compressor rejects 60%. The resulting savings paid for the device in four months.

For all the facts, write for bulletin GEC-629 or call your nearest G-E office. *Apparatus Dept., General Electric Co., Schenectady, New York.*

GENERAL ELECTRIC

687-36

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AUTOMATIC ELECTRIC RELAYS SWITCHES

This special—*and separate*—department has but one function . . . to process *your* orders promptly and accurately. Here, stocks of all standard parts are maintained, ready for expert assembly in accordance with your specific requirements. "Engineering Samples" are shipped within 10 to 14 days after receipt of order (for hermetically sealed relays, allow 10 days more). Quantity shipments can start within 30 to 60 days on schedules to meet your requirements. With high-geared volume production, thousands of these superior components are being delivered quickly.

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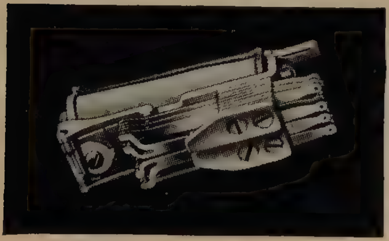
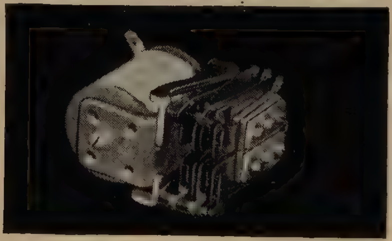


CLASS "B" RELAYS—For requirements up to 26 terminals—greater sensitivity, contact pressure, compactness, versatility. And here's dependable long life even under extremely high speed operation. Hermetically sealed, where desired, to maintain highest performance standards.



CLASS "S" RELAYS—For aircraft and other applications requiring small size, light weight, and hermetic sealing, if desired. Astonishing power in small space. Unaffected by extreme vibration, temperature changes, high humidity. Supplied with coils up to 10,000 ohms or more.

TYPE 45 ROTARY SWITCH—Up to 10 or more bank levels, adaptable to 25- or 50-point operation. Speed to 70 steps a second. Simpler . . . only one field adjustment. For d-c service or completely self-contained for a-c service to suit a wide variety of control applications.

For help on your control problems, call one of our field engineers, or write for literature. Address AUTOMATIC ELECTRIC SALES CORPORATION, Chicago 7, Illinois. In Canada: Automatic Electric (Canada) Ltd., Toronto.

RELAYS SWITCHES

AUTOMATIC ELECTRIC

CHICAGO

HIGH LIGHTS AND SIDE LIGHTS

The MPA "Special" Is On Its Way

Throughout the More Power to America "Special" are displays covering the complete range of electrical apparatus for industry

General Electric has unveiled its More ower to America Special, the biggest lectrical display kit ever built.

Almost a quarter-mile long, the 10-car xhibit train represents the first attempt to isplay, in one series of related exhibits, he complete range of products for the roduction, distribution, and industrial tilization of electric power.

The "Special," launched on the rails by he Apparatus Department, was in New ork City on the first lap of a nationwide our. It will visit approximately 150 key ndustrial centers during 1950 and 1951.

The train will not be open to the general public during its tour, because the exhibits aboard the train have been designed specifically to interest those who produce electric power and those who put it to work in industry and the community.

It is filled with exhibits of more than 2000 of the most modern electric products, systems, and techniques. Wherever possible, actual apparatus has been displayed aboard the "Special." Where size and weight limitations have made this impractical, scale models or other representations have been used.

Storm Center for Indoor Hurricanes

A 300-mph blast of air can be generated the powerful wind tunnel used for eronautical research and testing at the Jniversity of Maryland's Glenn L. Martin chool of Engineering and Aeronautical ciences.

The blast of air is generated by the 250-hp electric-drive system, and wind peeds from four to 300 mph can be mainained accurately to within one-half of ne percent through a series of electronic ontrols. Linked to the drive system is a even-bladed propeller, 19 ft in diameter, vhich produces the airstream. Six fairngs, or vanes, behind the propeller prevent he air from twisting as it moves through he tunnel.

The wind tunnel building is approxinately 275 ft long, 125 ft wide, with a vorking cross section 7.75 by 11 ft, and is quipped with twelve photoflood lamps reessed into the walls, providing light for hotographing models at any time during ctual testing.

The new tunnel is used by students specializing in aeronautical research and for development and research work by aeronautical concerns and the government.

Engineers inspecting the streamlined nacelle of the new wind tunnel

Talking Traffic Light

The city of Syracuse (N. Y.) is experimenting with an electronic device as a means of keeping pedestrians safety conscious while crossing a busy intersection.

Each time the signal changes, a friendly voice warns pedestrians to be cautious while crossing. Voice for the signal is provided by an Electronic Narrator, a tape recording machine, installed in the signal control box with a loudspeaker atop the signal's housing.

Without being rewound or reset, the talking traffic signal repeats six different messages.

Remote-control Dolly for Radioactive Areas

A one-armed robot on wheels, which can close doors, turn valves, take apart and reassemble complex machinery, and perform virtually every task the human hand can perform, has been developed for work in radioactive areas.

The device, known as a "tool dolly," is rolled on narrow-gage tracks into radioactive areas where men cannot go, and is operated by remote control from a shielded adjacent room. Power and control are supplied through six cables, which lead to the power source and control devices.

The dolly weighs approximately five tons, and resembles a railroad handcar; mounted on it is a telescoping arm, on the end of which are double clamps, similar to artificial hands used by amputees. The arm can be extended or shortened, raised or lowered, by remote control. The "hand" itself is capable of a wrist-bending motion, rotation, and gripping.

There are six small electric motors in the arm and hand, and two dozen of them in the entire unit. In addition to the gen-

(Concluded on following page)

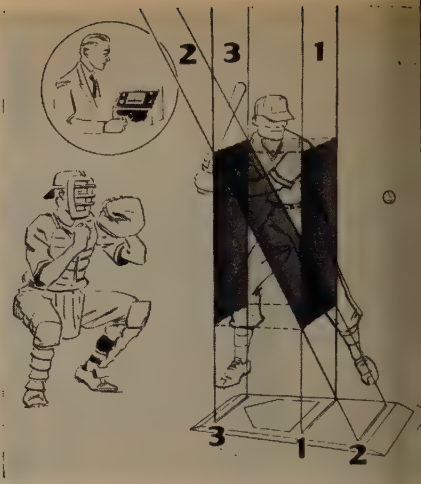
eral-purpose hand, the dolly is equipped with an hydraulically driven ram, electrically controlled, which can deliver a four-ton push; rotating devices for opening and closing valves; and several special attachments for taking apart machinery.

A man operating the dolly must be able to see what the device is doing, and various methods for observing its movements from behind a shield can be used. To make observation easier, the dolly has been equipped with a three-foot mirror, which is mounted high on the carriage and can be turned vertically or horizontally by remote control, so as to show the operator a reflection of work hidden from his direct line of sight.

The valve-turning attachments are equipped with electric "feelers," which indicate to the operator whether or not the valve handle is properly centered in the grasp of the turner.

Electronic Umpire

An outstanding addition to one of baseball's spring training camps this year was a cross-eyed electronic umpire, which "calls 'em closer" than any normally endowed arbiter, and does so without fear of argument. This fearless ruler of homeplate was developed (for training use only) as an aid to improved pitching and batting, and operates even on an overcast day, but not at night.



The two main units of the electronic umpire: the ground box, where three electric eyes aimed at differen angles spot the pitched ball in definite sequence; and the cabinet containing recording and strike indicating equipment, which can be located anywhere within 25 ft from home plate

In the thin metal ground box, upon which home plate is located, are lenses and mirrors which enable three electric eyes to "fence in" the strike zone by looking at the sky through three slots. When a ball passes through the strike zone, it casts its shadow on the electric eyes in a definite sequence (see cut), thereby creating electric impulses that light the strike-indicating lamp in a nearby cabinet.

An inside or outside ball does not cas its shadow on the eyes, because they "see" only the width of the plate. A high or low ball casts its shadow in an improper sequence and the lamp does not light, thu indicating a "ball." The equipment ca be so adjusted that the strike zone outlined will fit any batter, regardless of hi height.

Another attribute of this umpire is it ability to register the speed of a pitched ball.

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The mistaken young man who quit the patent office . . .

Back in the 1880's, a young man quit the patent office. It was a perfectly good job except for one thing: There wasn't any future in it. You could, as he explained, walk through the place and see for yourself that just about every possible thing had been invented.

He was, of course, just as wrong then as he would be today almost seventy years later. In a world where nothing is impossible and many things are still unknown, progress is limited largely by lack of imagination.

In electronics alone, a "normal" quarter of a century's development has been crowded into the past half dozen years. And patent requirements of this single industry probably equal the total work of the patent office when this mistaken young fellow resigned.

SPRAGUE

SPRAGUE ELECTRIC COMPANY
North Adams Massachusetts

PIONEERS IN ELECTRIC AND ELECTRONIC DEVELOPMENT

ague Telecaps*, the first truly practical phe-
: molded paper tubulars, introduced a new
in trouble-free small capacitor performance,
ther under "normal" or exceptionally dif-
t operating or "shelf" conditions.

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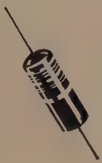
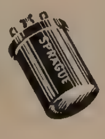
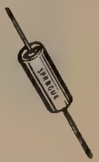


Revolutionary new dry electrolytic capacitors to match television's exacting needs are another Sprague pioneering development. Conservatively rated up to 450 volts at 85°C., these long-life electrolytics are outstandingly stable.



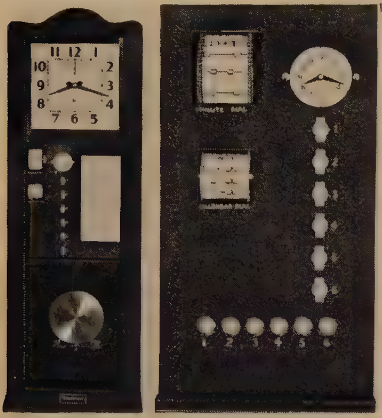
Sprague Subminiature Paper Capacitors, hermetically sealed in metal cases with glass-to-metal solder-seal terminals, are designed to be as good as, and often better than, larger units.



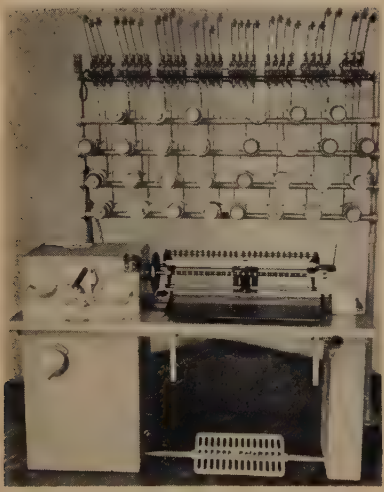
NEW PRODUCTS: AND WHAT THEIR MAKERS HAVE TO SAY ABOUT THEM

Clock and Program Machine

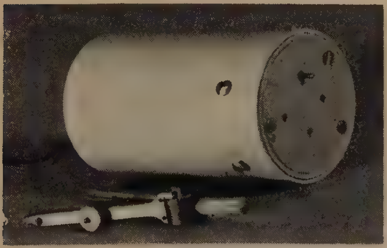
The Master-Pro clock-and-program machine for use in schools, institutions, and industries. Acting as director of an entire time-and-signaling system, it performs two functions: a master clock by sending out electrical impulses once each minute to all secondary clocks and time recorders, and a program instrument by sounding signals. Operating directly from the power line, the master section sends 24-volt d-c impulses over a two-wire circuit to all connected clocks and time-recording units. To set a schedule time, it is necessary only to insert a simple contact roller on a plainly marked dial. Minute-interval schedules can be set, and more than 100 separate signals can be set on each circuit. A device is provided to silence signals during any 12-hr period.—*Cincinnati Time Recorder Co., Cincinnati 14, Ohio.*



Clock and Program Machine



Coil Winder



Integrator Motor

Terminals

New multielectrode hermetically sealed terminals of Kel-F thermoplastic resin for high- or low-temperature operation. The operating potential of the new terminal is 3000-volt peak at sea level and 1500 volt at an altitude of 50,000 ft. Current rating is 15 amp rms. The known operating temperature range is set at 200 C to −195.8 C. Insulating resistance is 1,000,000 megohms and water absorption is 0.000. Applications include communication equipment designed for tropical and sub-zero climates, and a wide range of uses are known in other fields where maximum sealing, high resistance to heat, and freedom from tracking are paramount.—*Molding Corporation of America, 58 Weybosset St., Providence, R. I.*

Ultralow-frequency Oscillator

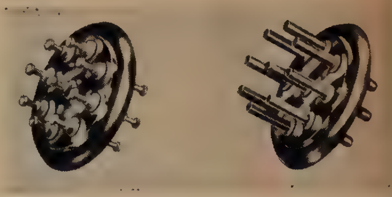
A new wide-range ultralow-frequency oscillator, Model 410-A, for design and test of servo-mechanisms, control instruments, and feedback amplifiers; for vibration checks and medical research; and with timing and production controls. It combines the sub-audio with the normal audio frequencies and provides both sine- and square-wave outputs over the entire frequency range from 0.02 to 20,000 cps. Six frequency bands are provided, each covering a full decade, with continuous control of frequency. A single 11-in. illuminated direct-reading logarithmic scale is used on all bands.—*Krohn-Hite Instrument Co., 580 Massachusetts Ave., Cambridge 39, Mass.*

Coil Winder

A new manually operated coil-winding machine, No. 108, designed for the production of paper-insulated coils in multiple or stick form. The machine can be adjusted quickly to accommodate changing requirements of wire size, coil length, and diameter. A leadscrew type of traverse permits lead attachment procedures without disturbing the traverse setting. The gearing is independent of the length of traverse and is designed as a turns-per-inch system. A double-throw spring-loaded jaw-reversing clutch operates the leadscrew. Control of release through hardened gears insures an accuracy of one tooth. The leadscrew has a thread with 10 turns per inch, resulting in accuracy at the coil that is within 0.003 in. Power is supplied by a ½-hp a-c constant-speed motor; speed range is 400 to 2200 rpm.—*Universal Winding Co., Providence, R. I.*

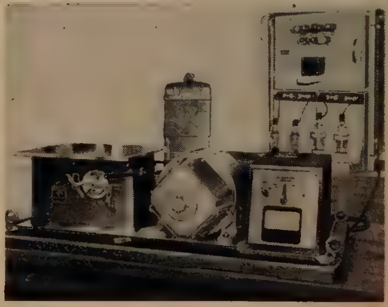
Integrator Motor

A new integrator motor for applications requiring the time integral of a d-c voltage. Speed of the motor is proportional, within half of one percent, to applied voltages between −15 and +15 volts; and within a quarter of one percent through all of the range except near zero voltage, or reversal point. Angular shaft displacement over any given period therefore is proportional to the integral of applied voltage during that period. The output shaft may be geared or directly coupled to an indicator or other instrument load. The armature of the motor is geared to a single output shaft at a ratio of 500:1. Alternate ratios of 100:1 are available.—*Specialties, Inc., Skunks Misery Rd., Syosset, L. I., N. Y.*



Terminals

Ultralow-frequency Oscillator



Vibration Fatigue Tester

Vibration Fatigue Tester

The 100-HA-T vibration fatigue-testing machine provides smooth stepless acceleration from 10 to 100 cps. This is accomplished manually by turning a knob on the control panel, or it can be done automatically with uniform acceleration or deceleration, completing the cycle within one minute. The cycle can be stopped at any point so that readings can be taken. Infinite speed range is provided by a General Electric Thy-Mo-Trol electronic drive. This unit makes possible the desirable performance characteristics of a d-c motor drive through the use of a-c power.—*All American Tool & Mfg. Co., 1014 W. Fullerton Ave., Chicago 14, Ill.*

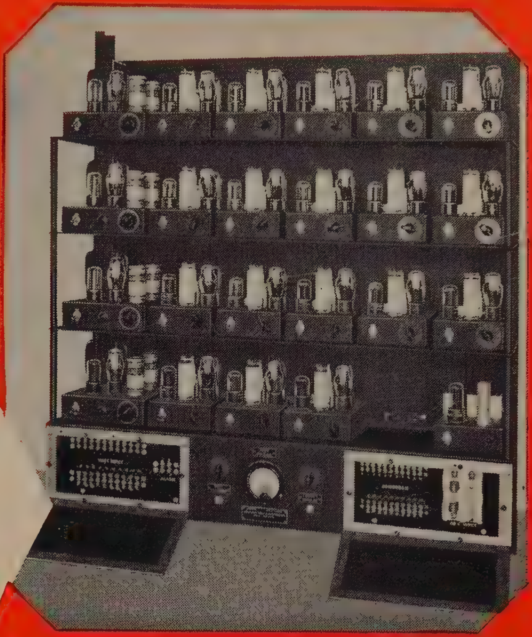
Paper Tensiometer

A new paper tensiometer keeps a continuous check on the tension of paper during manufacturing and reeling operations. Formerly, the problem of maintaining the proper tension was a critical one, but this new instrument can be so connected to electronic controls of paper machinery that it will adjust the machinery automatically, maintaining whatever paper tension the operator may require. The tensiometer consists of a small steel roller, riding on top of the moving paper. Changes in paper tension shift the roller's position slightly. The roller is fixed at the end of an arm which bends as the roller rises or falls. The bending of the arm is measured by a strain gage, which is connected to electronic controls of the paper machinery. Any change in roller position causes the machinery to adjust itself to restore the desired tension.—*General Electric Co., Special Products Division, Schenectady 5, N. Y.*

NEW

DRIVER-HARRIS ELECTRONIC TESTING

Obsoletes Previous Methods of Testing Enameled Wire Insulation



This revolutionary Dielectric Continuity Tester of Driver-Harris checks the quality of coating on 19 strands of wire simultaneously—as the wire leaves enameling furnaces. Tap switches on the test units are calibrated in impulses per minute required to operate an alarm. With the speed of the wire known, and also the maximum number of faults per 100 feet permitted by specification, each test unit is readily set to operate in conformance with the terms of the test imposed.

In order to guarantee the quality of a spool of enameled wire, *every inch* of the wire should be checked for dielectric faults, not just a few feet. In general practice, however, only a short sample of wire is examined. This is passed through a mercury cup held at a fixed potential, and shorts through the insulation are indicated on a voltmeter. If faults do not exceed a specified maximum for a given length of wire, insulation throughout the *entire* spool is assumed to be satisfactory.

This inefficient, compromise method has two important disadvantages: (1) the small portion of wire tested may not truly represent the condition of insulation throughout the spool; (2) insulation failures are not discovered until long after the enameling process is completed.

By checking insulation *continuously,* as wire leaves the enameling furnaces—the only 100% dependable way—Driver-Harris' new test equipment obsoletes such ineffectual and wasteful procedure.

So long as specifications are met, the new Driver-Harris electronic tester permits the enameling process to continue uninterrupted. When the *rate* at which faults occur approaches the maximum number of faults permitted by specifications, the test mechanism sounds an alarm and a record is made on a moving chart.

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TRADE LITERATURE

Aluminum Paint—A handsomely designed brochure emphasizing how aluminum paint can be used to best advantage. It explains that uses of aluminum paint by business and industry fall into three classifications: (1) for metal, concrete, masonry, and similar nonabsorbent surfaces; (2) for weather-exposed wood; and (3) for interior heated surfaces and decorative uses. Three spreads effectively display 30 photographs of actual applications, ranging from oil refineries and coal tipples to industrial fencing and bridges. A question-and-answer section and an aluminum coverage table are included. A copy will be sent without cost to requests made on business letterheads. Thirty-two pages. Titled "Painting with Aluminum."—*Aluminum Company of America, Pittsburgh, Pa.*

Ceramic Properties—A chart giving the mechanical and electrical properties of AlSiMag custom-made technical ceramics, covering 17 of the more frequently used compositions. It simplifies and speeds the selection of the most useful composition for the individual requirement. Four pages. Chart No. 501—*American Lava Corp., Chattanooga 5, Tenn.*

Cable Splicing Kits—Information is given on unit splicing kits for all types of cables, and all necessary information for ordering these kits for any type of cable joint is included. Four pages. Bulletin J50.—*G & W Electric Specialty Co., 7780 Dante Ave., Chicago 19, Ill.*

Electrostatic Precipitation—A profusely illustrated publication explaining how electrostatic precipitation works. Case histories of seven typical installations are given. The various methods of electrostatic precipitation are described, as well as the electric equipment applicable to each method. Sixteen pages. GEA-5212.—*General Electric Co., Apparatus Dept., Schenectady 5, N. Y.*

Instruments and Glass Specialties—Details of new components of process control instruments are offered in four catalogs: Pycnorator instruments for measuring and controlling fluid density and specific gravity. Eight pages. Catalog 76; mercury manometer flow meters for measuring flow rate of liquids, vapors, and gases in piping systems. Eight pages. Catalog 37; glass pipe and fittings for laboratory, pilot plant, and special services. Four pages. Catalog 94; and Glo-Tech precision-bore glass specialties of round, square, and capillary tubing for use in high-accuracy barometers and manometers, burettes, etc. Six pages. Catalog 95.—*Fischer & Porter Co., Hatboro, Pa.*

Lathes—A new series of Light Ten precision lathes is the subject of a bulletin containing several illustrations. Specifications and prices of four models of the lathe are given; attachments and accessories are listed also. Eight pages. Catalog No. L-10. *South Bend Lathe Works, South Bend 22, Indiana.*

Reducing Valves—A handy reducing-valve selection chart for those who specify valves occasionally, but who lack engineering background necessary to do the job easily. The chart used in conjunction with an accompanying detailed bulletin also helps determine proper sizes of valves including those which are suitable for deadend service as well as those which are not. Twenty-four pages. Chart and Bulletin 148.—*Klipfel Manufacturing Co., Div. Hamilton-Thomas Corp., 1000 Weller Ave., Hamilton, Ohio.*

Switches—Detailed information on the use of Esco Type P multiple rotary snap switches for a wide variety of services in control and transfer of electric circuits. Cutaway views, circuit diagrams, sub-assembly photographs, and dimensioned drawings provide necessary information for an understanding of the operating principles. Twelve pages. Catalog 1950-P.—*Electric Switch Corp., Weymouth 88, Mass.*

Wiring System—A booklet explaining a new remote-control method of lighting home and farm. The details of the principles of this system are given together with the advantages its offers. Installation methods and materials are illustrated, and a number of circuit diagrams are included. Sixteen pages. Titled "Remote Control Wiring."—*General Electric Co., Construction Materials Dept., Bridgeport 2, Conn.*

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Digest

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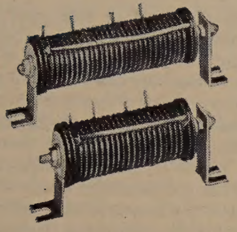

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TIME METERS—TO CHECK TUBE LIFE

G-E time meters, with dependable Telechron* motor drive, are especially useful in recording the operating time of radio transmitters or other electronic devices so that tubes may be replaced before they fail. They record operating time in hours, tenths of hours, or minutes, and are supplied for 11-, 115-, 230-, or 460-volt operation. The case is of molded textolite to harmonize with other G-E 3½-inch instruments mounted on the same panel. You'll find more description along with dimensions and pricing information in Bulletin GEC-472.

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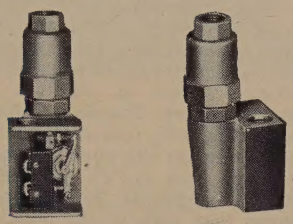

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This new G-E battery-operated electronic voltmeter combines the portability of an ordinary low-sensitivity multimeter with the high sensitivity and versatility of a line-voltage-operated vacuum-tube voltmeter.

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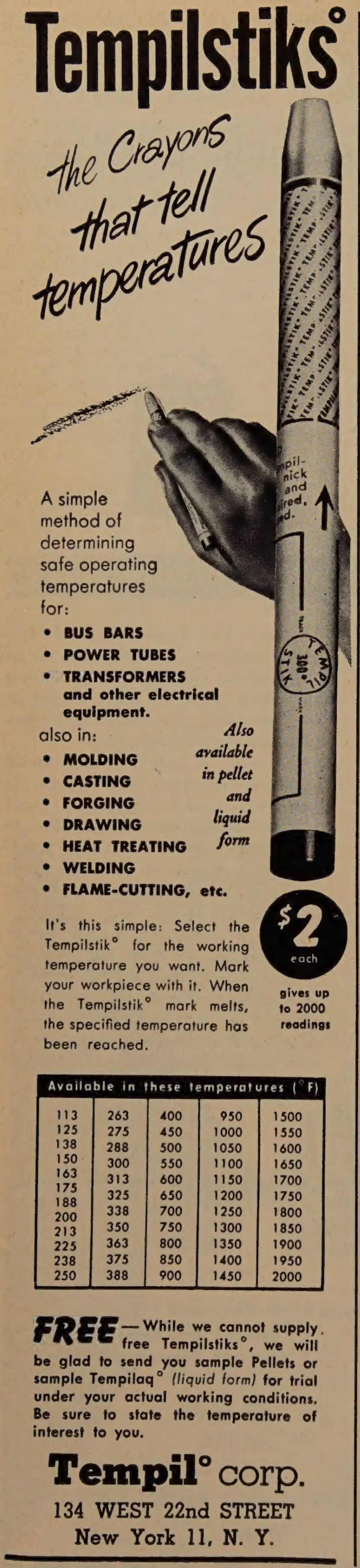

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BOOK REVIEWS

(Available books may be purchased through the GENERAL ELECTRIC REVIEW for domestic delivery: none sent on approval.)

A CHEMISTRY OF PLASTICS AND HIGH POLYMERS

Patrick D. Ritchie—Cleaver-Hume Press Ltd., London (Interscience Publishers, Inc., New York). 1949. viii+288 pp. $4.50.

Dr. Ritchie's book, as stated in the preface, has been planned with a view to filling a rather unexpected gap in the literature of high-polymer chemistry. It will appeal to organic chemists in general and to workers in the high-polymer field in particular.

The book is particularly clearly written, in spite of its brevity. The insertion of the date in parentheses after the worker's name gives the particular subject an historical and chronological sense in addition to the chemistry involved. The chemical material is presented logically and includes data and theory right up to the minute. The use of abbreviations such as "P" for phenol and "F" for formaldehyde lend a feeling of conciseness that adds to the book's value. Suggestions for Further Reading which follow each chapter, while covering the field more or less well, will not be complete enough for those who desire to go into the original papers themselves.

There are remarkably few typographical errors, the most obvious of which appears on page 1, where a quotation is attributed to J. B. Priestley in 1940. Another slight oversight occurs on page 99 in the equation near the bottom in which $5H_2O$ should clearly be $5CH_2O$.

Especially to be recommended is the chapter on Structure and Physical Properties. In a brief space, the correlation between the chemical structure and the results of physical tests and electrical measurements is established so that extension of the principles can be made for both practical purposes and theoretical thinking.

K. B. GOLDBLUM

COMMUNICATION CIRCUITS (3rd Edition)

Lawrence A. Ware and Henry R. Reed—John Wiley & Sons, Inc., New York. 1949. x+403 pp. $5.00.

Transmission circuits for all frequency ranges in use today are treated here in what is intended as a first-course textbook in communication engineering. With such a wide range of subject matter it is impossible to cover each topic completely, and the authors have made no effort to do so. The material is well organized and is on a relatively high technical plane for an introductory undergraduate course.

A fairly extensive treatment of transmission lines is approached from the circuit point of view in the beginning of the book and is later analyzed by the use of Maxwell's equations and wave concepts.

Three chapters are devoted to classical filter theory and impedance transformation. Constant-K and M-derived filters, conventional impedance transforming circuits, and the use of transmission lines as impedance transforming devices are all considered. The final five chapters deal with ultrahigh-frequency transmission in wave guides and coaxial lines. Maxwell's equations are used to find the field configurations and to study the characteristics of transmission in these circuits.

In this third edition, the authors have introduced the rationalized MKS system of units, radically revised the material on transmission line parameters, and placed more emphasis on the use of Maxwell's equations and the ultrahigh frequency aspects. These revisions are quite justified in the light of modern developments.

D. H. KUHN

SCIENTIFIC AUTOBIOGRAPHY AND OTHER PAPERS

Max Planck—Philosophical Library, New York. 1949. 192 pp. $3.75.

Towards the end of the nineteenth century the majority of scientists believed that physics had reached a climax of completeness, that it had become a subject of "classical" beauty. Max Planck had contributed a great deal to this accomplishment, notably through his papers clarifying the concept of entropy. Then in 1900, when he was 42 years old, his painstaking analysis of experimental data on black-body radiation compelled him to introduce a foreign element into the classical structure. Energy absorbed or emitted by a radiator was to be "quantized" and proportional to the frequency of radiation. The factor of proportionality appeared to be a universal constant, Planck's h.

One might think that it took the aggressiveness of a revolutionary mind to propose and defend this novel idea. Planck's authorship of quantum theory is particularly remarkable in view of the fact that he was, and remained until his death in 1947, a most conservative thinker and research worker. His loyalty to classical physics prevented him from fully exploiting the possibilities of his discovery. While Planck "cultivated the virgin soil," it was for Einstein, Bohr, Heisenberg and a whole generation of physicists to "pick the flowers."

Planck takes us along the arduous path of a theoretical physicist in the late nineteenth century. The academic positions were few and far between; recognition, even among colleagues, was meager. Characteristically, his story ends soon after 1905, when Einstein's contribution transformed quantum theory from an oddity to a powerful heuristic principle.

The second half of Planck's life was devoted to delivering lectures to learned societies and to the general public. The book contains four of his latest lectures. His philosophy is unique and cannot be fully appreciated without an acquaintance with his earlier lectures. Yet there is the curious fact that the parent of quantum theory does not see eye to eye with Niels Bohr, its godparent, whose "Copenhagen spirit" infused into the theory a profound meaning universally appreciated by the younger generation.

Planck's "physical reality" is the dream, not yet come true, of a strictly classical physicist, and appears quite metaphysical to the modern reader. He calls upon an "ideal intellect" immune to "scientific analysis" to see, unobstructed by Heisenberg's indeterminacy, a physical reality pervaded by strict classical causality. Science struggles to approach the seeing of the "ideal intellect." Religion postulates "a supreme power ruling the world" according to immutable "laws" of nature. Surely this supreme power possesses the ideal intellect. It is Max Planck's belief that "no matter where or how far we look, nowhere do we find a contradiction between religion and natural science."

The book is a most fascinating document n the history of physical thought. Its ranslator, Frank Gaynor, has done an dmirable job.

GERHARD DESSAUER

HYSICS AND CHEMISTRY OF CELLULOSE IBRES

. H. Hermans—Elsevier Publishing Co., nc., New York. 1949. xxii+534 pp. $7.50.

The author has here presented a summary f scientific work which he considers of importance to a further understanding of the nature of cellulose. The book is divided into hree parts: the first part deals with the structure of cellulose (constitution, crystalinity, molecular weight, chemical behavior, tc.); the second part, with cellulose fibers; he third part, with viscose rayon. Physical nd chemical-physical work is emphasized ver purely chemical studies.

There are many references throughout the ext, and the special references at the end f each chapter in Part I should be helpful. The European literature cited is particularly extensive; this is possibly the most useful feature of the book. The reviewer eels that the American literature has not been covered so carefully. For example the Fuoss-Mead Osmometer (1943) is not listed under osmotic methods for molecular weight determination, although the reference to heir paper is given (incorrectly) under viscosity methods. The intriguing structure for cellulose proposed by E. Pacsu (1947) is not mentioned. The light-scattering method for molecular weight determination, proposed by Debye (1944) and applied by Stein and Doty (1946) to cellulose acetate, is not considered.

The book is not easily read, undoubtedly the result of the difficulty of translation of a foreign idiom into readable English. Occasionally terms are employed which are not in common usage in the United States—e.g., "gelatination." The book is well constructed and printed, but the reviewer would have preferred the paragraphs indented in the usual manner. For some reason the author's name is not listed in the author index, although his published work is referred to throughout the book.

Because of the limitations in scope, this book is not recommended to the reader with only a casual or general interest in cellulose. Because of its intensive treatment of the subjects covered, however, the book is recommended to serious scientific workers in this field, particularly to those doing research related to the structure of cellulose and to the production of viscose rayon.

W. E. CASS

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QUANTUM THEORY OF FIELDS

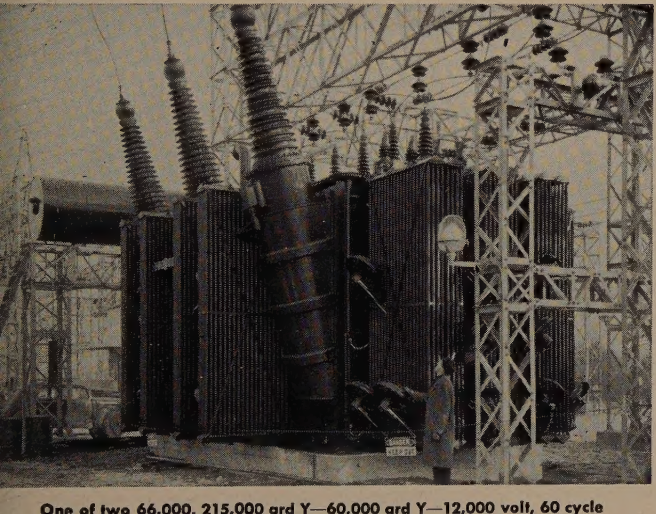
Gregor Wentzel—Interscience Publishers, Inc., New York. 1949. ix + 224 pp. $6.00.

This is a translation of a German text that provides a basic understanding of the quantum theory of interacting fields without, however, attempting to solve its fundamental difficulties. Its purpose is didactic and provides enough introduction to enable the reader to follow up with the original literature on the subject.

The book starts with the formalism of the variational principle, the quantization rules of elementary quantum mechanics, and the requirements for Lorentz invariance. It continues with specific examples of field types which are associated with particles of various spin, charge, and mass values. One chapter is devoted to the scalar field, first assuming an electrically neutral real field, then—to describe charged mesons—introducing a complex field.

A whole chapter is devoted to the vector meson field employing from the start a complex field. The interactions between light and electrons are described in the next chapter on quantum electrodynamics, where the divergence difficulties of the self-energy are treated also in greater detail. The wave fields of the electrons are subjected to a process of quantization in a following chapter. The book closes with a brief description of the more complicated tensor fields for particles with integral spins and their generalization to the construction of spinor fields for particles with half-integral spins.

GABRIEL KRON



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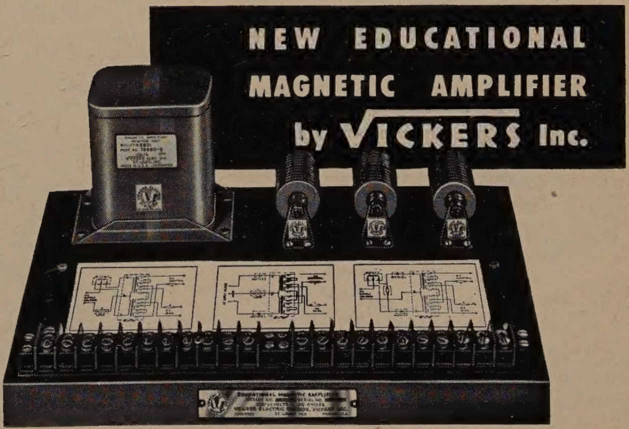

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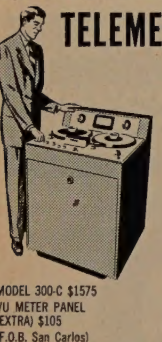

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LIBRARY NOTES

ON ARTICLES IN OTHER TECHNICAL JOURNALS

AIR CONDITIONING

ABSORPTION REFRIGERATION APPLIED FOR AIR-CONDITIONING OFFICES, by A. A. Giannini. *Heat & Vent.*, Jan. 1950; v. 47, p. 65.

A new development in the absorption cycle, using water as the refrigerant, which makes possible the air-conditioning of office space by a central-system absorption machine. Data are presented on the operation of the cycle and machine, the steam consumption, and operation characteristics.

ROOM AIR CONDITIONERS—PAST AND PRESENT, by R. W. Morgan. *Refrig. Engng.*, Jan. 1950; v. 58, p. 34.

A survey of the design history of this equipment since 1928, with a discussion of engineering problems still to be solved.

CORROSION

CORROSION OF MOLYBDENUM-BEARING STAINLESS-STEEL WELD METALS, by Anton L. Schaeffler and R. David Thomas, Jr. *Weld. Jour.*, Jan., 1950; v. 29, p. 13s.

Corrosion of as-welded stainless-steel specimens as affected by the type and location of the carbide and sigma precipitates. Effect of ferrite and heat treatments is indicated for each type.

ELECTRIC CABLES

CORROSION TESTING OF BURIED CABLES, by T. J. Maitland. *Corrosion*, Jan. 1950; v. 6, p. 1.

The corrosion testing methods employed in connection with buried toll cables of various types of construction are described in detail.

WHY WE CHOSE 15-KV GAS-FILLED CABLE FOR CHEMICAL-PLANT FEEDERS, by R. E. Philbeck. *Elec. Wld.*, Feb. 13, 1950; v. 133, p. 73.

Use of gas-filled cables for two-mile parallel feeders.

ELECTRIC MOTORS

HOW SMALL CAN A MOTOR GET? by R. S. Elberty. *Elec. Mfg.*, Jan. 1950; v. 45, p. 91.

The design problems in reducing motor size.

HOW TO LUBRICATE FOR LONGER ELECTRIC MOTOR LIFE, by A. F. Brewer. *Steel.*, Jan. 16, 1950; v. 126, p. 56.

How to lubricate an electric motor effectively: to understand the bearings, how they are installed, and what provision is made for their lubrication.

FURNACES

DEVELOPMENT OF FURNACES FOR MALLEABLE-IRON ANNEALING, by C. H. Martin and H. J. Hammond. *Foundry*, Jan. 1950; v. 78, p. 80.

Operation of typical equipment currently employed in malleable-iron foundries is described.

GAS TURBINES

AUXILIARY POWER FOR LARGE, TURBINE-POWERED AIRCRAFT, by H. J. Wood and F. Dallenbach. *Soc. Auto. Engrs. Jour.*, Jan. 1950; v. 58, p. 67.

Describes an all-pneumatic power system obtaining compressed air from the main engines and from a special form of auxiliary gas turbine.

LUBRICATION AND LUBRICANTS

GIVE LIFE TO HYDRAULIC SYSTEMS, by A. G. Bergstrom and R. Q. Sharpe. *Mach. Design*, Jan. 1950; v. 22, p. 80.

Describes proper selection of oil and careful design of components.

TRACING CAUSES OF SLUDGES AND DEPOSITS IN LUBRICATING SYSTEMS BY USE OF MODERN MICROCHEMICAL METHODS, by J. S. Wiberley and J. B. Rather, Jr. *Lubrication Engng.*, Feb. 1950; v. 6, p. 11.

The common causes of deposit formation and the interpretation of analytical results are briefly treated. Some actual case histories are described where microchemistry made possible both identification of the material and the subsequent explanation as to its presence.

MACHINE-SHOP PRACTICE

HIGH-SPEED SHORT-RUN PRODUCTION ON AUTOMATIC BAR MACHINES, by George H. DeGroat. *Mach.*, Jan. 1950; v. 56, p. 133.

The advantages gained by the use of these machines: high production rates, the elimination of secondary operations, and accurate work without the constant attention of skilled operators.

MEASURING INSTRUMENTS

PROPORTIONAL COUNTER X-RAY SPECTROMETER, by W. Bernstein and others. *Nucleonics*, Feb. 1950; v. 6, p. 39.

Useful for the energy range of 1 to 50 kev, this instrument provides a simple method for measuring x-ray spectra.

STEEL-HEAT TREATMENT

QUENCH-CRACKING FACTORS, by D. W. McDowell, Jr. *Iron Age*, Jan. 12, 1950; v. 165, p. 64.

An investigation of the factors governing quench cracking in light- and heavy-walled tubes is described.

VIBRATIONS

ULTRASONICS—A NEW CHEMICAL ENGINEERING TOOL, by Dudley Thompson. *Chem. Engng. Prog.*, Jan. 1950; v. 46, p. 3.

Considers selected applications of ultrasonic energy to the field of chemical engineering.

WELDING

DESIGN DETAILS FOR STUD WELDING, by R. W. Murdock. *Prod. Engng.*, Jan. 1950; v. 21, p. 135.

Minimum plate thicknesses for different sizes of studs, strength of studs, required clearances for the welding gun, methods of stud location, and basic functional advantages of the process.

WELDMENTS VS. CASTINGS, by Lawrence Naberhaus. *Weld. Engng.*, Jan. 1950; v, 35, p. 28.

Cost comparisons for several parts produced as a weldment and as a cast-iron structure, in lots of 1, 10, and 50.

X-RAYS

CALCULATION OF X-RAY MASS ABSORPTION COEFFICIENTS, by John A. Victoreen. *Jour. App. Physics*, Dec. 1949; v. 20, p. 1141.

Gives an empirical method of calculation and complete tables of constants for all elements.